DEVELOPMENT AND IMPROVEMENT OF ORGANIC COMPOUND EMISSION INVENTORIES FOR CALIFORNIA

FINAL REPORT

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ABSTRACT

The objectives of this study were to (1) review the 1979 statewide organic solvent emission inventory for accuracy and completeness; (2) perform a market balance on the most important solvent species; (3) evaluate the procedures used by the ARB and local agencies to obtain, process and interpret solvent emissions data; (4) develop methods for upgrading the statewide emission inventory; (5) and update and improve those portions of the statewide emission inventory corresponding to solvent use in the South Coast and Bay Area Air Quality Management Districts.

A survey of 114 large solvent-using firms was conducted to verify information presently in the ARB's Emission Data System (EDS) for 1979. Addresses were missing, incorrect or incomplete for 24 percent of the respondents. Standard Industrial Classification (SIC) codes were incorrect for 12 of the 49 respondents. Devices and processes were missing from the records for a significant number of firms. EDS classifications for processes were incorrect for about half the firms responding. Except for cases of devices and processes which were improperly included or omitted, these misclassification problems are not likely to lead to serious errors. They do, however, make it extremely difficult to obtain useful information on emissions of individual solvents or on emissions from particular industries or processes. The failure to take emission abatement devices into account resulted in a 117-ton per year overestimate of total organic gas (TOG) emissions from two facilities. The geometric mean positive and negative discrepancies between EDS values and our emission estimates were 11.1 and 1.8 tons/year, respectively. If our estimates are correct, then the EDS overestimates emissions for all the reporting firms by 492 tons/year, or 13.5 percent. Errors in Universal Transverse Mercator coordinates exceed 0.5 km in about half the cases where we verified the location reported in the EDS. (As an expedient and cost-effective measure the UTM coordinates were assigned to facilities by a computer program which resulted in mislocation errors as great as 0.5 km. The ARB considers only the location of major stacks to be critical for modeling purposes.)

The methods used by the ARB to estimate area source emissions from dry cleaning, degreasing, cutback asphalt and road oil use, solvent recycling, domestic solvent use, use of surface coatings, and pesticides application were reviewed. Significant methodological problems were found for dry cleaning, asphalt and domestic solvent use. An improved relationship between dry cleaning emissions and population was determined. A comprehensive survey of asphalt use showed that road oil use and emissions may be correlated with road mileage, but that cutback asphalt use and emissions may not be. The emission factor used to estimate domestic solvent uses was judged to be too high.

The solvent composition and national use of a wide variety of formulations such as paints, adhesives, personal care products and household products were determined. Total solvent use and individual species use were apportioned to California, then to each county by several methods developed for the study.

Over 6,500 industrial firms were surveyed to obtain data on purchase, direct use, incorporation in product, recycling and disposal of about 70 solvent species and groups. As a check on our results, producers of all the major solvents of interest were surveyed to obtain data on their sales to California users and distributors. Results from these surveys, along with those of our investigation of indirect solvent use, were scaled up to estimate solvent use and emissions by SIC code, chemical species, and county.

Aliphatic hydrocarbons account for 45 percent of all the solvent mass used directly in California industry. Other important solvent classes are ketones, alcohols, chlorinated hydrocarbons, and aromatic hydrocarbons.

The total use of organic solvents in the South Coast, Bay Area, San Diego and San Joaquin Valley air basins in 1980 was between 1.2 and 1.6 billion lb. Direct and indirect use accounted for about 871 ± 184 and 493 million lb, respectively. The heaviest use of solvents occurs in Southern California. Los Angeles, San Mateo, Alameda, San Diego and Orange Counties have the highest use per county.

From our survey results, we estimate that emissions from solvent use in the four major air basins were between 258,000 and 294,000 tons in 1980. The corresponding EDS estimate for these basins in 1979 falls within this range. Our estimates are higher than the EDS values for the South Coast Air Basin and lower for the other basins. The counties having the highest estimated solvent emissions are Los Angeles, Orange, San Diego, Santa Clara, Alameda and San Bernardino.

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FINDINGS AND CONCLUSIONS

1.1   REVIEW OF THE EMISSION DATA SYSTEM (EDS)

The Emission Data System (EDS) is the computerized file in which the Air Resources Board (ARB) maintains records of both mobile and stationary source emissions. Our review of the EDS consisted of a survey to verify the accuracy and completeness of certain records and an evaluation of methods used to calculate several types of organic solvent emissions.

1.1.1   EDS Verification Survey

The original objective of our survey of the EDS was to identify those portions of the organic solvent emissions inventory which were most in need of upgrading. To accomplish that objective, we had planned to obtain information from over 1,000 facilities. Early in the project, however, the ARB requested us to place most of our emphasis upon the market balance. (See Section 1.2.) The new objectives of the EDS Verification Survey then became (A) to identify the major types of error in the EDS, quantifying them where possible; and (B) to obtain correct data for updating EDS records corresponding to the limited number of facilities surveyed.

1.1.1.1 Structural Problems

(1) Of the 114 facilities (chosen at random from those having 20 ·tons or more of organic solvent emissions in 1979) to which detailed questionnaires were sent, 7 had gone out of business and 49 provided complete information.

(2) Facility addresses were missing, incorrect or incomplete for 24 percent of the respondents.

(3) Standard Industrial Classification (SIC) codes were incorrect for 12 of the responding firms. In only one case did the error appear to be typographical. Because the ARB's Category of

Emission Source (CES) code is defined in terms of SIC codes (as well as source classification codes), 33 CES numbers in the inventory must be changed.

(4) Of the 49 responding firms, 9 had emission-producing devices which were not recorded in the EDS; 20 devices were missing. Some of the omissions were due to aggregation of two or more physical devices into one for the purpose of reporting.

(5) More than one quarter of the facilities reported having processes in addition to those recorded in the EDS; 38 processes were thus unaccounted for. At least some of these omissions may have been due to use of overly flexible or arbitrary classification criteria.

(6) The EDS contains 35 incorrect processes among 20 of the reporting firms. The common types of errors in classifying devices and processes were:

● Designation of conveyorized degreasers as open-top vapor degreasers;

● Ending Source Classification Code (SCC) numbers with 99 ("not classified") when an appropriate classification was available;

● Inclusion of a solvent among thinners when it is actually used for cleanup;

● Designation of styrene and other cross-linking agents in resins as solvents;

● Inclusion of devices and/or processes which never existed or which were taken out of service before 1979; and

● Improper designation of coating type (e.g. enamel instead of adhesives).

Except for cases of devices and processes which were improperly included or omitted, these misclassification problems are not likely to lead to serious errors. They do, however, make it extremely difficult to obtain useful information on emissions

of individual solvents or on emissions from particular industries or processes.

(7) Very few of the facilities in the survey have devices for abating volatile organic compound (VOC) emissions. The EDS omitted abatement devices for two facilities. As a result, VOC emissions from these facilities are over-estimated by 117 tons/year.

(8) A large percentage of the facility personnel who supply annual data to local districts appear to have a poor understanding of how emissions are estimated and what information is expected of them.

(9) Emission factors suggested by the South Coast Air Quality Management District (SCAQMD) for direct solvent use (e.g. in degreasing and addition of thinners to paints) are all within 5 percent of those we estimated from a review of commercial solvent density data.

1.1.1.2 EDS Emission Estimates

(1) Discrepancies between our estimates (or facility-reported estimates) of emissions from the responding firms and the emissions reported in the EDS were found in almost all cases. These discrepancies ranged from 0 to 334 tons/year per facility.

(2) In 30 of the 41 cases where 1979 data were available, the absolute discrepancy (i.e. positive or negative) was greater than 1 ton/year, which, given uncertainties in the raw data, is the minimum reasonably significant error.

(3) The geometric mean positive and negative discrepancies per facility were 11.1 and 1.8 tons/year, respectively. Positive errors (those resulting when the EDS value exceeded our estimate) outnumbered negative ones.

(4) If our emission estimates are correct, then, for the reporting firms, the EDS overestimates emissions by 492 tons/year, or 13.5 percent.

(5) The largest emission errors in the sample were the result of

- Omission of major devices and/or processes from the EDS;
- Inclusion of devices which are no longer in service; and
- Failure to take into account emission control equipment.

1.1.1.3 Errors in Universal Transverse Mercator (UTM) Coordinates

(1) The method by which the SCAQMD converted from a one-mile square grid system to UTM coordinates had a potential for creating significant errors in the resulting coordinates. These errors could result in further problems when the facilities are included in gridded photochemical models.

(2) UTM coordinates for a subsample of 27 of the facilities in our survey were determined to within 0.1 km. In 13 cases, the location reported in the EDS exceeded 0.5 km, which is an error of concern to modelers. One third of the subsample facilities' locations are in error by more than 1 km.

1.1.2 Emission Estimation Methodologies
1.1.2.1 Dry Cleaning

(1) Methods used by air pollution control districts (APCDs) and air quality management districts (AQMDs) appear to provide reasonably accurate estimates of point source emissions. Some confusion may result from improper use of SCC codes, however.

(2) About 37 percent of the dry cleaning emissions reported as area source emissions in the EDS were calculated by a population-based apportionment method recommended by the ARB.

(3) One important source of error in the ARB area source method is its assumption that national use of perchloroethylene in dry cleaning increased between 1978 and 1979; in reality, it decreased.

(4) Another potential problem is the assumption that dry cleaning solvent emissions are directly proportional to population. We performed numerous regression analyses on data from counties in the San Joaquin Valley Air Basin to explore this assumption. A log-linear relationship was found to fit the data better than the best linear relationship.

(5) Use of our regression equation for Monterey, San Luis Obispo, Santa Cruz, Shasta and Yolo Counties results in an aggregate emissions estimate of 262 tons, compared to the 916 tons reported by the EDS. We believe that the EDS estimate of 1,997 tons of dry cleaning emissions in San Diego County may also be in error; however, our regression equation could not be applied because San Diego County's population exceeds the range for which the equation was calculated.

(6) While the aforementioned findings imply that the EDS overstates dry cleaning emissions, review of our market balance data for perchloroethylene indicates that the amount of that chemical used in dry cleaning may be understated. The best way to resolve this seeming contradiction would be to perform detailed surveys of the dry cleaning industry in California.

1.1.2.2 Degreasing

(1) The method used by the ARB to estimate area source emissions from degreasing in manufacturing and maintenance industries assumes 365-days/year operation. This assumption is likely to lead to an overestimate of annual emissions.

(2) The ARB's area source methodologies for cold cleaning emissions associated with automobile shops is reasonable; however, a county-by-county survey of degreasing solvent use would probably provide more accurate information.

1.1.2.3   Cutback Asphalt and Road Oil

(1) The SCAQMD apportions cutback asphalt use and emissions by county according to each county's fraction of state population. Since cutbacks and road oils are used heavily in sparsely-populated rural areas, this method does not seem reasonable.

(2) The SCAQMD also assumed that the great bulk of the emissions from this source occur in the summer. Given the year-round warm climate of the South Coast Air Basin, this assumption may be invalid.

(3) The BAAQMD apportions asphalt use and emissions according to road mileage. We believe this method to be preferable to that of the SCAQMD.

(4) The Fresno County APCD method is based upon a survey of actual cutback and asphalt use by city and county road departments. We believe that this is the best method of all.

(5) For area source emissions not estimated by the aforementioned districts, the ARB apportioned total California cutback asphalt and road oil use among counties according to road mileage. However, the ARB had not taken into account a revision by the U.S. Department of Energy of the 1979 California sales data upon which the emission estimates are based. If the revised DOE figures are used, then cutback and road oil emissions would be higher by 15 and 28 percent, respectively, than the ARB estimates.

(6) To test the assumption that county cutback and road oil emis-
     sions are proportional to road mileage, SAI conducted a survey
     of actual use in most of the state's counties and large cities.
     The correlations between road oil use and emissions and road
     mileage were found to be statistically significant but weak
     (about 0.5).   The corresponding relationship between cutback
     emissions and road mileage was not significant at the 95-per-
     cent confidence level.

1.1.2.4   Solvent Waste Recovery and Reclamation

     Factors used to estimate emissions from solvent reclamation facili-
ties appear to be reasonable.   No alternative estimation methods were devel-
oped.

1.1.2.5   Domestic Solvent Use

(1) The ARB uses an assumption of 1.1 lb of solvent emissions per
     1,000 persons.   By comparing our estimates of indirect solvent
     consumption (see Section 1.2.2) category-by-category with those
     which comprise the ARB emission factor, we conclude that this
     emission factor should be changed to 0.88.

(2) To our knowledge, the ARB has no area source CES number for use
     of automotive products.   At least 9,000 tons of emissions may
     thus be unaccounted for.

1.1.2.6   Surface Coatings

(1) The BAAQMD instructs facilities in its inventory to report the
     organic solvent content and solvent density associated with the
     surface coatings they use.   The method is preferable to the
     SCAQMD's practice of providing the facilities with emission
     factors.

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(2) In making our own estimates of emissions from the facilities in our EDS Verification Survey, we found that the actual solvent densities of enamels, lacquers, sealants and other coatings varied over a wide range. While the factors recommended by the SCAQMD may represent reasonable averages, they may be significantly in error for individual facilities.

1.1.2.7 Pesticide Use

(1) Methods used by the ARB to estimate total VOC emissions from pesticide use appear to be adequate.

(2) Data for speciating these emissions were unavailable.

1.2 SOLVENT MARKET BALANCE SURVEY RESULTS

In order to obtain an independent estimate of total California organic solvent use and emissions, as well as use and emissions of the 20 most important solvent species, SAI surveyed chemical producers and users and developed methods to apportion national use of solvent-containing formulations to the state. Our overall conclusion is that the market balance approach, while feasible at the national level, cannot be used to its fullest capability at the level of a state, since crucial data are simply unavailable for individual states. Furthermore, given the complexity of solvent use patterns, it is not feasible to attempt to estimate total solvent use as the sum of uses of individual species. The approach was very useful, on the other hand, in providing a wealth of data on the solvent species of interest.

1.2.1 Producer Survey Results

(1) Of the 85 chemical producers which were asked to provide information on their sales of solvent species to California users and distributors, 78 responded. (The assistance of the ARB legal staff was necessary in some cases to obtain cooperation.)

(2) At least some sales information was obtained for 53 solvent species and classes. All solvent classes were covered well by the results, except for the aliphatic hydrocarbons (including kerosene and Stoddard solvent).

(3) Methanol had the highest reported California sales, (137 million lb in 1980). Other major solvent chemicals were ethyl alcohol (82.9 million lb), methyl chloroform (64.9 million lb), perchloroethylene (63.9 million lb), toluene (62.9 million lb), and methylene chloride (60.8 million lb).

(4) The results of our survey compared favorably with pre-survey estimates of the availability of only some of the chemicals for use in California as a solvent. Our method is therefore useful only for providing order-of-magnitude estimates.

1.2.2   Indirect Solvent Consumption

Solvents are present in a wide variety of formulations used in manufacturing, commercial enterprises and in the home. After determining the solvent weight percent and chemical composition of major products, we apportioned national consumption figures to California by several means. Our findings were as follows.

1.2.2.1   Paints and Coatings

(1) Data on national use of 21 individual solvent species and groups were obtained from the National Paint and Coatings Association (NPCA). Use of each solvent in original equipment manufacture (OEM), architectural and special purpose coatings, and in thinners was included in the NPCA data set.

(2) Factors for apportioning national totals to California were developed for each coating subcategory; among these were production worker hours, autmobiles produced, number of single-family homes, road miles and inhabitants.

(3) We estimate that 261.6 million lb of solvents were contained i
surface coatings and 129.7 million lb of solvents were added to
coatings as thinners in California in 1980.

(4) OEM, architectural coatings, special purpose coatings and thin-
ners accounted for 39.0, 15.1, 12.8 and 33.1 percent, respec-
tively, of the solvent used in paints and coatings.

(5) Aliphatic hydrocarbons comprise 32 percent of the solvent used
in paints and coatings in the state. Other important solvents
in these formulations are xylene (13 percent), toluene (10
percent), and methyl ethyl ketone (6 percent).

(6) The most heavily used solvents in thinners are toluene (17
percent), methyl ethyl ketone (16 percent), ethyl alcohol (12
percent), xylene (11 percent), and aliphatic hydrocarbons (10
percent).

1.2.2.2   Personal Care Products

(1) About 6.7 million lb of organic solvents were contained in the
personal care products covered by our investigation.

(2) Ethyl alcohol and isopropyl alcohol accounted for 79 percent of
the solvent used in personal care products in California in
1980.

(3) Use of solvents in nail polish and nail polish remover are
estimated to have been 272,000 lb and 800,000 lb, respectively.

(4) Approximately 140,000 lb of propylene glycol was used in shav-
ing cream.

(5) Deodorants account for about 140,000 lb of propylene glycol use
in the state.

(6) About 3.0 million lb of ethanol and 32,000 lb of propylene glycol were used in aftershave and electric pre-shave lotion.

(7) Approximately 2.3 million lb of isopropyl alcohol was used as rubbing alcohol.

1.2.2.3   Household Products

(1) Over 4.2 million lb of solvents were contained in the household products used in California in 1980.

(2) Use of ethylene glycol monobutyl ether in general purpose household cleaners is estimated to have been 700,000 lb.

(3) About 1.2 million lb of ethylene glycol monoethyl ether and 420,000 lb of isopropyl alcohol were used in window cleaners.

(4) The total use of solvents in spot removers is estimated to have been 421,900 lb. Solvent species and groups include aliphatic hydrocarbons, methyl chloroform (1,1,1-trichloroethane), methylene chloride, perchloroethylene, toluene, trichloroethylene, and xylene.

(5) Ethylene glycol use in pens was about 37,000 lb.

(6) A minimum of 1.4 million lb of solvents (mostly hexane, toluene, and acetone) was used in household adhesives. We have reason to believe that this estimate is significantly below the actual value, but it is the best we could derive from available data.

1.2.2.4   Automotive Products

(1) We estimate that 165 million lb of ethylene glycol was used as radiator antifreeze in California.

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(2) Methanol use in windshield washer antifreeze and gasoline lin
antifreeze was 14.7 million lb and 1.2 million lb, respectively.

(3) About 2.4 million lb of ethylene glycol monoethyl ether was
used in brake fluids in California in 1980.

(4) Other automotive products which contain solvents include gaso-
line additives, carburetor cleaners, spray de-icers, and engine
cleaners. Sales data were available only for carburetor clean-
ers, which contained 9,000 lb of toluene.

1.2.2.5   Industrial Adhesives and Sealants

(1) Data from a national survey of industrial adhesives manufactur-
ers were used to estimate California use in construction, trans-
portation, manufacturing, and other industries.

(2) California use of industrial adhesive solvents in 1980 was
estimated to be 11.3 million lb. This estimate may be an order
of magnitude too low.

1.2.3   Direct Solvent Use by Industry and Solvent Type

(1) Detailed information on individual solvent purchase, incorpora-
tion in liquid products, recycling and disposal was obtained
from 1,154 facilities. Additional data on type of product
produced and number of employees permitted us to scale up re-
sults according to industry type.

(2) A matrix of solvent species versus SIC code was developed for
each major solvent group. These matrices, which are too de-
tailed to present here, will be found in Section 7.3.

(3) Aliphatic hydrocarbons constitute 45 percent of all the solvent
mass used directly in California industry. Other important
solvent classes include ketones (12.6 percent), alcohols (11.0

percent), chlorinated hydrocarbons (8.4 percent), and aromatic hydrocarbons (7.0 percent). The remaining 16 percent of solvent use is accounted for by glycols, glycol ethers, esters, fluorocarbons, paint and lacquer thinners, and other compounds.

1.2.4   Total Solvent Use by Geographical Area

(1) The total use of organic solvents in the four largest California air basins (South Coast, Bay Area, San Diego and San Joaquin Valley) in 1980 was between 1.18 and 1.55 billion lb.

(2) Of this total, 870 ± 184 million lb were used directly in industry and commerce, e.g. for addition to coatings, degreasing, dry cleaning, and as process solvents. Indirect solvent use, i.e. use in formulations such as paints, household cleaners, and automotive products, amounted to 493 million lb. The uncertainty in this estimate is probably on the order of 25 to 50 percent.

(3) The heaviest use of solvents occurs in Southern California, whose two major air basins (South Coast and San Diego) account for 59.1 percent of the direct solvent use and 51.0 percent of the indirect solvent use.

(4) The counties having the heaviest total solvent use are, in decreasing order, Los Angeles, San Mateo, Alameda, San Diego and Orange.

(5) Detailed charts showing the flow of solvents through uses, recycling and emission were prepared for 20 chemicals.

1.2.5   Solvent Emissions by Geographical Area

(1) Total organic solvent-related emissions in the four major air basins, as estimated by SAI from the results of our surveys and projections from literature data, were 276,000 ± 18,000 tons in 1980.

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(2) If emissions resulting from incorporation of solvents as ingredients in liquid products are eliminated from consideration, then our estimate of total solvent emissions in the four basins is 254,000 to 288,000 tons/year. The EDS estimate of 277,000 tons/year for corresponding emission source categories falls within this range.

(3) Our basin emission estimates are higher than the corresponding values in the EDS for the South Coast Air Basin, and lower for the other basins.

(4) According to our calculations, indirect solvent use emissions are higher than those for direct use.

(5) The South Coast Air Basin is responsible for 62.7 percent of the direct use emissions and 61.4 percent of the indirect use emissions.

(6) The counties having the highest estimated solvent emissions are, in decreasing order, Los Angeles, Orange, San Diego, Santa Clara, Alameda and San Bernardino.

1.2.6   Uncertainties in SAI's Emission Estimates

In the market balance summaries for individual solvent species and in the estimates of solvent use and emissions in the four major air basins, uncertainty estimates were presented, wherever possible, as $\pm$ values. Not all the uncertainty could be quantified, however.

(1) Uncertainty in solvent use estimates derived from national values results from uncertainties in national use rates, in the densities of some solvent-containing formulations, in the values for the apportionment bases, and in the apportionment method itself.

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(2) For solvent use and emissions estimates based upon apportionment, it would not be too conservative to estimate an uncertainty of $\pm$ 50 percent.

(3) The raw data reported by respondents to our industrial solvent consumption and disposal survey are, in the aggregate, reasonably accurate, since the largest solvent users generally keep the most detailed and accurate records of solvent purchases; thus most of the error in the raw data is probably associated with the smallest fraction of the use.

(4) Uncertainty in the extrapolation of survey results to totals for the State, SIC codes, individual chemicals, and counties arises from the large variance in solvent use per firm, the need to aggregate some four-digit SIC codes to the three-digit level, and lack of size information for some of the zero-solvent users.

(5) Uncertainties in weighted average emission factors for the SIC codes surveyed were quantified by a statistical analysis (Section 5.4.1) of the EDS, and have been expressed as 95-percent confidence limits.

(6) The uncertainty in solvent use and emissions estimates based upon our survey data was quantified by use of confidence intervals for emission factors, and by performing each scale-up calculation in two ways: by firm size class (within each SIC code) and for the SIC code as a whole.

2.0
RECOMMENDATIONS

On the basis of our findings in the study, we make the following recommendations.

(1) The EDS Verification Survey, or something similar, should be expanded to include enough facilities to enable a statistically valid estimate of the overall error in the EDS. Given the mean and standard deviation of the error in our survey sample, we estimate that a survey of 400 facilities would be necessary to detect an absolute emissions error (i.e. positive or negative) of 20 percent. The new survey should be stratified such that strata having higher variances would be sampled more heavily. Possible strata could include counties, SIC codes, or processes.

(2) The EDS should be updated to incorporate the data obtained in the verification survey. Especially large errors should be checked by the pertinent local districts.

(3) More explicit, uniform guidelines for classifying emissions by source category are absolutely essential; two engineers confronting the same situation in two different APCDs should choose the same classification code. Sponsorship of statewide training progress by the ARB is one alternative.

(4) The Bay Area Air Quality Management District's requirements for facilities to specify the volume percent, density and species composition of solvents in coatings is preferable to the use of standard emission factors; it should be employed by all the local districts for estimating VOC emissions from individual facilities.

(5) If the ARB's modeling staff considers the errors in UTM coordinates discovered by this study to be significant, the coordinates for all point sources in the major air basins should be checked.

(6) We do not recommend continued use of the ARB's method for estimating dry cleaning emissions for area sources. A stratified sample survey of emissions from dry cleaners in the larger counties would be highly desirable, given the large potential error in the ARB's estimate. Indeed, surveys of this type should be conducted in all the major air basins every two years or so. Facilities should be stratified by employee size class to enable extrapolation of the sample results to the county as a whole.

(7) A carefully designed survey of emissions from the use of cold cleaners in automobile repair shops should be performed.

(8) Since DOE data on California cutback asphalt and road oil use may not be available in the future, surveys of California producers of these materials may be necessary.

(9) Additional efforts to obtain data on California use of solvent-borne adhesives may be desirable, given the lack of complete data from the industry.

(10) Although we were able to update the emission factor for solvents used in consumer products, we were unable to obtain data on several components of that factor, including polishes, perfume, toiletries, shampoos, mouthwash and hand lotion. We recommend a survey, similar to our survey of chemical producers, to obtain data directly from manufacturers. Since these data are likely to be highly proprietary, assistance of the ARB legal staff would be required.

(11) Future studies of the use and emissions of individual chemical species should cover <u>all</u> uses (e.g. as feedstocks, consumer products, etc.), thereby avoiding the complications involved in focusing upon a single use.

(12) The market balance approach is not recommended for California-specific studies.

3.0

INTRODUCTION AND BACKGROUND

3.1   INTRODUCTION

3.1.1   Purpose and Objectives of the Study

The California Air Resources Board (ARB) maintains a statewide inventory of volatile organic carbon (VOC) emissions, including those due to the use of organic solvents. In 1979, solvent emissions were estimated by the ARB to account for about 11 percent of VOC emissions from both mobile and stationary sources. An inventory is only as good as the data of which it is comprised, and there was concern over the reliability of the emission information stored under certain solvent-related process and activity categories. Furthermore, the ARB needed an independent estimate of both total organic solvent use and emissions and those of individual solvent chemical species.

In recognition of the potential deficiencies in the statewide emission inventory, the ARB requested that research be performed to upgrade the system. The objectives of this study were:

- To review the 1979 statewide emission inventory data base for accuracy and completeness;
- To perform an organic solvent market balance on the most important solvent species;
- To evaluate the procedures used by the ARB and local agencies to obtain, process and interpret solvent emissions data;
- To develop methods for upgrading the statewide emission inventory; and
- To update and improve those portions of the statewide emission inventory corresponding to the South Coast and Bay Area Air Quality Management Districts.

3.1.2   Outline of the Research

Research under this contract was conducted between June 1981 and November 1982. The major elements of the study were as follows.

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3.1.2.1　EDS Verification Survey

In order to ascertain the nature of errors in the Emission Data System (EDS), a two-part questionnaire was sent to 114 facilities selected at random from the set of facilities having at least 20 tons per year of total organic gas (TOG) emissions. Questions in the first part were designed to verify information about each plant's manufacturing activity, location and number of employees. The second part consisted of a computer printout of emissions information currently in the 1979 statewide inventory. Respondents were asked to change erroneous entries and/or supply missing data. This survey and its results are described in Section 4.1.

3.1.2.2　Review of Emission Estimation Techniques

Methods used by the ARB and by local air pollution control districts (APCDs) to estimate point and area source emissions from dry cleaning, degreasing, use of cutback asphalt, solvent recycling, use of consumer products, application of surface coatings, and pesticide formulation and application were reviewed and critiqued. County, city and state road departments were surveyed to determine use of cutback asphalt and road oil. Alternative methods were proposed for dry cleaning, asphalt, and consumer products. This portion of the research is described in Section 4.2.

3.1.2.3　Organic Solvent Market Balance

An attempt was made to make an independent estimate of total California solvent use and emissions, as well as those of 20 solvent chemical species. Calendar year 1980 was chosen as the base year for market balance data. The following approaches were used.

Solvent Producers Survey

Producers of most of the solvents of interest were asked to report the total amounts of each chemical sold to California consumers and distributors in 1980. Survey methods and results are described in Chapters 5 and 7, respectively.

Direct Industrial Solvent Consumption and Disposal Survey

Questionnaires were sent to over 6,500 industrial users of organic solvents. Respondents were asked to report amounts of individual solvent species purchased, incorporated in liquid products, recycled and disposed in 1980. Our survey methods are described in Chapter 5. Survey results were used to estimate solvent use by Standard Industrial Classification (SIC) code, and use and emissions by county and air basin. Use and emissions estimates are found in Chapters 7 and 9.

Review of Indirect Solvent Use

Indirect solvent use consists of use of formulations, such as paints, inks, and household cleaners, which contain solvents. In this portion of the research we determined the solvent content of a variety of industrial and consumer formulations and apportioned national use thereof to California. Our methods and results are discussed in Chapter 6.

Market Balance Dossiers and Flowcharts

Using the results of the aforementioned research, we constructed detailed dossiers on 20 of the most heavily-used solvents. The flow of each chemical through the state was then diagrammed. Dossiers and flowcharts are presented in Chapter 7.

3.2   THE STATEWIDE EMISSION INVENTORY FOR ORGANIC SOLVENTS

The purpose of this section is to acquaint the reader with the system used by the ARB to estimate and keep track of emissions of organic solvents. A complete description of the system has recently been published by the ARB (CARB, 1982).

3.2.1   System Structure

The Emissions Inventory and Data Processing Branches of the ARB's Technical Services Division maintain the statewide emission inventory in a

computerized file called the Emission Data System (EDS). Emission data are stored for both point and area sources. Point sources are relatively large emission sources having well-defined locations. In general, the EDS includes sources which emit at least 25 tons per year of total organic gas s (TOG), although the trend is to include more and more smaller sources. For example, the EDS contains data on virtually all the dry cleaning plants in the South Coast Air Basin, despite the fact that most of them emit less than .0 tons per year of TOG (Thomas, 1982).

Area emission sources are those for which emissions are estimated in the aggregate. They include facilities which are too small to include in the point source inventory, as well as activities, such as use of cutback asphalt, which are distributed over a large geographic area.

Emission data in the EDS are classified according to several schemes. The earliest is according to a system developed by the U.S. Environmental Protection Agency (1976a). Each pollutant-emitting device in a facility is assumed to have one or more processes associated with it. Processes are in turn identified by Source Classification Codes (SCCs). A typical solvent-related SCC is 4-01-002-03 (open-top vapor degreasing with perchloroethylene). More recently, the ARB developed a classification system based upon two new codes (ARB, 1980). The Category of Emission Source (CES), represented by a five digit number is a unique combination of SCC and Standard Industrial Classification (SIC) code. Every CES code has associated with it an "A" code, which refers to the major activity (e.g. paint manufacturing) related to the CES category; a "P" code, which refers to the major process or device (e.g. degreasing); an "E" code, which refers to the emission mode (e.g. evaporation) and material (e.g. solvent); and a "D" code, which provides additional information about the emissions. Table 3.2-1 shows, for example, how emissions from a perchloroethylene degreaser in the aircraft industry would be classified.

Table 3.2-1

EXAMPLE OF HOW EMISSIONS ARE CLASSIFIED IN THE EDS
(Perchloroethylene Degreasing in the Aircraft Industry)

Code Type	Code	Description
SIC	3721	Aircraft
SCC	4-01-002-03	Open-top vapor degreasing/perchloroethylene
CES	22632	(Described in terms of the other codes)
Activity (A)	A295	Transportation equipment
Process (P)	P320	Degreasing
Entrainment and Materials (E)	E211	Synthetic-evaporation
Dimension (D)	30D31 21D2	Aircraft equipment/parts manufacturing/perchloroethylene

Source: CARB, 1980.

3.2.2   Data Collection and Emission Estimation

Emission-related data for point sources are collected by the local air pollution control districts (APCDs) and regional air quality management districts (AQMDs) and submitted annually to the ARB. The AQMDs have their own computerized files but must submit data to the ARB according to the EPA/EIS format. Smaller districts maintain hard-copy files and submit data on forms provided by the ARB. Recently, the ARB has developed the capability of providing emission inventory analysis and reporting services to the districts which lack computer systems of their own (Bradley, 1982).

To estimate point source emissions, the APCDs and AQMDs most frequently use emission factors based upon their own experience and judgment and/or those published by the U.S. Environmental Protection Agency (e.g. USEPA, 1976b). These emission factors, modified if abatement devices are used, are multiplied times a throughput rate to obtain emissions. In some cases, emissions are determined directly through source tests. Revised emission factors are then used.

Area source emissions are based upon some sort of activity factor, whose nature varies with the type of emissions. For example, emissions of solvents in household products in a given county may be assumed to be proportional to the number of households or the number of persons in that county. The ARB has recently published a compilation of methods for assessing area source emission (Ipps, 1932). Other methods have been recommended by the EPA (Lamason and Lahre, 1980; USEPA, 1981). As part of this project, we reviewed these and other methods.

3.2.3   Potential Problem with the EDS

Armentrout (1979) has identified ten types of errors which commonly occur in the development and updating of emission inventories. These are summarized in Table 3.2-2. Another problem, which our EDS Verification Survey showed to be fairly widespread, was misclassification of emission sources. Classification errors are sometimes due to the dependence by the APCDs and AQMDs upon inadequately trained personnel to assign codes. In other cases, it

Table 3.2-2

COMMON ERRORS IN EMISSION INVENTORY DEVELOPMENT AND USE

Type of Error	Common Source of Error
Missing facilities or sources	Permit and inventory systems out of phase; errors in estimating potential emissions; lost paperwork; problems with computer file updates.
Duplicate facilities or sources	Name changes through corporate acquisitions; use of multiple data sources with different source numbering schemes.
Missing operating or technical data	Ambiguous data request forms; intentional deletion by facility; inadequate followup procedures.
Erroneous technical data	Misinterpretation of data request instructions; assumed units, faulty conversions, etc; intentional misrepresentation by the facility; poor handwriting.
Improper facility location data	Recording coordinates of facility headquarters instead of the operating facility; inability of technicians to read maps; changes in UTM zones.
Inconsistent area source categories or point source sizes	Failure to designate inventory cutoffs.
Inaccurate or outdated data	Mixed use of primary and secondary data without a standard policy.
Errors in calculations	Transposition of digits; decimal errors; entering wrong numbers on a calculator; misinterpreting emission factor applications.
Errors in emission estimates	Imprecise emission factors; applying the wrong emission factor; errors in throughput estimates; improper interpretation of combined sources; errors in unit conversions; faulty assumptions about control device efficiency.
Reported emissions wrong by orders of magnitude	Recording the wrong SCC code for subsequent emission calculations by computer; ignoring implied decimals on computer coding sheets; transposition errors; data coding field adjustment.

Source: Armentrout, 1979.

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is the system itself which creates problems, as engineers try to force real-world device and process configurations into the EPA's SCC definitions. As Mann (1982) has noted, some SCCs define specific items of equipment, others define process input or output streams such as quantity of fuel burned, and still others define only a particular product or raw material without any specification of processing equipment.

Another problem with the current statewide emission inventory for organic solvents is that it contains only meager information on the speciation of emissions. The Bay Area AQMD and, to a lesser extent, South Coast AQMD require facilities to report all the chemical species used and emitted. Although SCC numbers are available for many individual solvent species, such as those used in paint thinners, these numbers are infrequently used.

3.3. REFERENCES

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4.0

EVALUATION OF THE EMISSION DATA SYSTEM

Our evaluation of the ARB's Emission Data System (EDS) consisted of two main activities. In the first, which is described in Section 4.1, we conducted a written and telephone survey of a random sample of major point sources, in order to determine whether the information corresponding to them in the EDS was accurate. The purpose of our other activity was to review the way in which emissions, especially those from area sources, are estimated. As is described in Section 4.2, we evaluated emission estimation techniques for dry cleaning, degreasing, cutback asphalt use, solvent disposal, domestic use of solvents, surface coating and pesticide manufacture and use.

4.1   EDS VERIFICATION SURVEY

The original objective of SAI's survey of the EDS was to identify these portions of the inventory which were most in need of upgrading. To accomplish that objective, we had planned to conduct a detailed survey of over 1000 point sources, distributed among roughly 50 combinations of county and category of emission source (CES) code. Early in the project, however, the ARB asked that we transfer the bulk of our program resources from the EDS evaluation to the market balance research. As a result, both the scope and the purpose of the survey were changed. (See Section 3.1 for a complete discussion.) The new objectives of the EDS verification part of the project became:

● To identify the major types of error in the EDS, quantifying them where possible; and

● To obtain correct data for updating EDS records corresponding to the limited number of facilities surveyed.

Given the low priority for this survey, it was decided jointly by the ARB and SAI to include only about 100 facilities, and that these should have minimum total organic gas (TOG) emissions of 20 tons/year.

4.1.1   Survey Methods

4.1.1.1   Data Base Creation and Management

At the start of the project, SAI obtained a copy of the latest version of the 1979 EDS from the Stationary Source Control Division. Facility and emission data were first placed on high-density (6250 bits per inch) tape at SAI's computer center in La Jolla. Before storage on the tape, the data were formatted and organized with System 1022, a general purpose data management software system which operates on DECsystem-10 computers. In a manner similar to that of the RAMIS system used by the ARB, System 1022 builds random access files with keys for accessing "attributes" (e.g. SIC code, TOG emission factor) and combinations thereof. Later in the project, the data base was transferred to a hard disk storage system for more convenient access and reduced cost.

4.1.1.2   Selection of Facilities

While we were correcting some data access problems resulting from our initial unfamiliarity with the EDS, the ARB furnished us with a list of facilities having TOG emissions (from all processes having ARB process codes between 300 and 399) greater than or equal to 20 tons per year. The ARB search found 640 such facilities, 501 of which were in the South Coast Air Basin. Firms for the survey were chosen with a random number algorithm on the Apple II Computer. In order to obtain a 20-percent sample, each firm was given a probability of 0.2 of being chosen. Since the choice was truly random, only 121 facilities were in fact selected by the program.

Finding facility and mailing addresses for the survey group proved to be more difficult than expected. The aforementioned ARB search provided us with county and facility identification numbers and the EDS field EISNAMEADDR, which included the facility name. In most cases the street addresss and/or the city name is included; in many cases no location data at all are provided. Using System 1022, we also searched the fields STREET, CITY, FACZIPCODE, and MAILZIPCODE. As will be discussed in Section 4.1.2, address information was lacking for several facilities. Some of the missing data were obtained from

local or regional air pollution control agencies, or from telephone director-
ies. One facility in Los Angeles County could not be located by any means.

Table 4.1-1 shows the geographical distribution of the original
sample. The surveyed firms represented 15.3 percent of the statewide station-
ary source solvent emissions in 1979. Orange and San Bernardino Counties were
especially well represented. As seen in the last column of the table, our
sample's distribution of emissions by county does not match the state's distri-
bution of stationary source solvent emissions very well. However, since our
intention was not to "scale up" from our survey results to the EDS as a whole,
the poor geographical representation was not of concern.

4.1.1.3 Questionnaire Design

Each of the chosen facilities was mailed a survey "package" consist-
ing of a cover letter, project authorization statement signed by the Chief of
the Air Resources Board's Research Division, secrecy agreement between SAI and
the ARB, general instructions, and a two-part questionnaire. The question-
naire forms are shown in Figures 4.1-1 and 4.1-2 while the other survey instru-
ments are included in Appendix A.

Both parts of the questionnaire were designed to be similar to the
"turnaround documents" used by the ARB and, to some extent, by the SCAQMD to
update emission inventory information. The forms show data which are present-
ly in the EDS, and which are to be changed if incorrect.

The purpose of Part I was to verify information about each facility's

- Name,
- Plant address,
- Mailing address,
- Standard Industrial Classification (SIC) code, and
- Number of employees

We originally planned to generate both parts of the survey using the System
1022 data base management program. Given the large number of missing and

Table 4.1-1

CHARACTERISTICS OF FACILITIES IN ORIGINAL SAMPLE FOR EDS
VERIFICATION SURVEY
(All emissions are of solvents from stationary sources)

County	No. Firms Selected	No. of SIC Codes	TOG Emissions (tons/yr)	Percent of EDS Emissions For County	County's Pct. of Statewide TOG Emissions
Alameda	5	4	730.5	12.7	6.3
Contra Costa	1	1	59.1	13.6	0.47
Los Angeles	69	48	6,888.1	14.5	51.6
Orange	18	16	2,727.4	24.5	12.1
Riverside	2	2	117.9	7.4	1.7
Sacramento	3	3	313.8	14.7	2.3
San Bernardino	8	8	1,480.2	41.4	3.9
San Diego	10	10	1,528.5	13.3	12.4
Santa Clara	4	4	213.8	4.9	4.8
Ventura	1	1	26.4	3.7	0.78
Totals	121	NA	14,085.7	15.3	

SCIENCE APPLICATIONS, INC./CALIFORNIA AIR RESOURCES BOARD
EMISSION DATA SYSTEM VERIFICATION SURVEY
PART I

Local District Permit/ID No.: 19-5041

Name of Firm: ALUM A FORM

A. Please correct the following if necessary:

Plant Address: 18915 Laurel Park   Mailing Address: 18915 Laurel Park

Compton, CA 90220   Compton, CA 90220

Telephone: 213-537-9050

Contact: Yoshio Kiyohiro

B. Your Standard Industrial Classification (SIC) code is listed as 3792 (travel trailer and camper manufacturing). If this is incorrect, report proper code _____. If you don't know your plant's SIC code, please describe your manufacturing activities or services.

_____

_____

C. How many employees are engaged in this type of production or service (do not include administrative personnel) _____

Total number of employees at your facility _____

D. On the attached map, please indicate the location of your facility. If your facility is large, indicate the approximate location of the major emission sources (stacks, tanks, etc.). If there are many sources, then show only the center of your main activity area.

Figure 4.1-1. EDS Verification Survey Form, Part I

SCIENCE APPLICATIONS, INC./CALIFORNIA AIR RESOURCES BOARD

EMISSION DATA SYSTEM VERIFICATION SURVEY

PART II

FACILITY NAME: ALUM A 'FORM   Survey ID 4

A. According to the ARB emission inventory, your facility has the following devices having solvent-emitting processes. Please cross out those devices and/or processes which are no longer used, and report any which are missing.

Device Number	Permit ID Device Name	Process	Process Description	Hrs/ Day	Days/ Week	Weeks/ Year
7	Adhesives booths	1	SURFACE COATING ADHESIVE	16	5	52

B. According to the ARB emission inventory, the devices listed above in Part II, section A, use the following controls. Please indicate any changes and estimate the efficiency of each device and the percentage of time that it is in operation. Note any controls which have been added or deleted.

Device Number	Device Name	Process	Device Control Num	Control Devices	Eff.	Pct. Time
7		1	0 0 0 0 0	None		

C. Please state for each device and process combination, how emission estimates were calculated. If the local APCD calculated the emissions, please indicate. Emission factors shown are those reported in the ARB emission inventory.

Device Number	Process	Emission Factor	Units (Pounds Per)	How emissions were estimated
7	1	1375.000	TONS COATING	

Figure 4.1-2.   EDS Verification Survey Form, Part II

D. For each device and process listed in Part II, Section A, please indicate the amounts (gallons or pounds) of each individual solvent (e.g. acetone, toluene, etc.) or solvent-containing substance (e.g. varnish, lacquer thinner, ink, etc.) you used in XXXX 1979. If you do not know the generic chemical name, give the brand name.

Solvent or solvent-Containing compounds Device 7 Process 1	Cleaning/ Degreasing 1	Used as Diluent	Incorporated in Liquid Product	Surface Coating	Amount Recycled
	-------	-------	-------	-------	-------
	-------	-------	-------	-------	-------
	-------	-------	-------	-------	-------
	-------	-------	-------	-------	-------

E. Thank you for completing this survey. If you have any questions, please contact DR. Michael Rogozen at (213) 553-2705.

Figure 4.1-2. EDS Verification Survey Form, Part II (Ctd).

incorrect addresses in the EDS, however, we found it more convenient to store corrected address information, descriptions of SIC codes and other pertinent data on floppy disk, and then to generate Part I with a word processor. Since most respondents were not expected to know their SIC codes, the form contains the presumed code (EDS variable FACSIC) along with our description. Respondents were given the opportunity to describe their manufacturing activities or services, so that we could determine the SIC code if necessary. The questions about number of employees was included so EDS survey data could be incorporated properly in our direct solvent consumption survey. (See Section 5.3.2.)

Attached to each Part I survey form was a street map (in most cases a page from a Thomas Brothers guide) believed to contain the plant's location. Respondents were asked to mark their precise location on the map. This question was included because a preliminary check of the EDS verification survey sample set had shown many Universal Trans Mercator (UTM) coordinates to be incorrect. Problems with the UTM data are discussed below.

The purpose of Part II of the questionnaire was to verify information related directly to organic solvent emissions. In order to minimize the burden on the respondents, yet obtain important data, we limited our survey to the following items:

- Identification of solvent-emitting devices and processes,
- Operating hours per day, days per week, and weeks per year,
- Emission control devices,
- Emission factors, and
- Amounts of individual solvents and solvent-containing substances used, incorporated in a liquid product, and recycled.

Forms were generated directly from SAI's version of the EDS, using the System 1022 software. To make the the form as clear as possible to the respondents, existing EDS information was arranged first by device and then, for each device, by process. It was hoped that upon seeing the values for the EDS variables PERMITID and DEVICENAME on the form, respondents would know exactly which devices were included. Unfortunately the EDS contained only a few local district permit numbers and no device names for the facilities in our survey.

We therefore had to make an educated guess as to the nature of each device and add it to the survey form. To aid us in guessing we included the EDS variables SCC3NAME and SCC6NAME on the form, and the eight-digit source classification code (SCC) on a separate printout.

Emission control devices are included in the EDS by a code number. It was therefore necessary to type a description of each device onto the survey form. Emission factors and units, as represented by EDS variables PROCESSRATE and EMISNFACTOR, were presented for verification. This section of the questionnaire proved to be confusing to the respondents, many of whom believed that emission factors and emissions were the same thing. Anticipating this, we included a question as to how emissions were estimated.

Finally, respondents were asked to report the exact type of solvents used for each device-process combination. Our objectives here were to (1) verify total solvent use (as the sum of uses of each solvent type); (2) determine actual emission factors for coatings, as distinguished from the values suggested on local districts' annual reporting forms; and (3) identify, wherever possible, chemical species and groups. The last of these objectives would serve our market balance effort and provide the ARB with more refined data for photochemical modeling.

4.1.1.4   Conduct of the Survey

Questionnaires were mailed between 25 August and 24 September. After about one third of the forms had been sent, it was discovered that we had inadvertently requested data for calendar year 1980, rather than 1979. Followup letters were sent to this first group of firms, informing them of the change in date. About 30 facilities contacted SAI by telephone for clarification of our requests; the item which, by far, required the most explanation was the emission factor. Follow-up calls by SAI were necessary for most of the returned surveys. In many cases, the EDS description of devices and processes was so deficient that lengthy telephone conversations were needed in order for us to determine precisely what the true configurations were. Some respondents included diagrams and detailed descriptions of production processes to aid us. Finally in most cases the respondents did not know the

organic solvent content of the coatings, inks and adhesives they used. It was necessary therefore to call numerous coatings manufacturers and distributors to obtain the information.

UTM coordinates were determined by measurement on U.S. Geological Survey (USGS) 7.5-minute maps, which were available at the UCLA Map Library. These maps show UTM coordinates at 1-km intervals; intermediate values were determined by interpolation. The error inherent in our measurement technique would not be expected to exceed the equivalent of 0.025 km. In cases in which respondents showed the outline of their facilities rather than a discrete emission point, our error in placing the facility on the USGS map may have been as high as 0.1 km. Only errors greater than 0.1 km, therefore, should be considered to be significant.

4.1.2   EDS Verification Survey Results

Seven of the 121 originally selected firms were not sent questionnaires. As noted above, one facility could not be located. The other six had so many processes that it would have placed an unreasonable burden on respondents to fill out the questionnaire. Of the 114 firms to which the survey forms were sent, 7 had gone out of business since 1979 and were unable to provide us with any information. We received useful information from 49 (43.0 percent) of the surveyed firms.

4.1.2.1   General Survey Results

Table 4.1-2 summarizes the information obtained from the 49 returned questionnaires. To preserve the anonymity of the responding firms, we have used our survey code numbers rather than local district identification numbers. Discrepancies between EDS data and information provided by each survey respondent are described in detail in Appendix B. The following are our general findings.

Facility Addresses

Since the EDS is often used as an information resource in conducting surveys of major point sources, it is essential that users be able to locate

Table 4.1-2

SUMMARY OF DISCREPANCIES FOUND BY EDS VERIFICATION SURVEY

Survey Code No.	Site Address a	No. of Devices b Missing	Incorrect	No. of Processes b Missing	Incorrect	Solvent Emissions (tons/yr) EDS	SAI	Diff.	Comments
3	C	1	0	1	0	43.0	16.9	26.1	
6	C	0	0	0	0	114.0	114.5	-0.5	
10	C	0	0	0	0	-	-	-	1979 data unavailable
11	C	0	0	0	0	22.0	57.0	-35.0	
12	C	0	0	0	0	702.0	367.0	335.0	SIC code incorrect
13	C	0	0	0	0	26.0	29.3	-3.3	
16	I	0	0	0	2/2	272.7	276.2	-3.5	Fiberglass plant
18	C	0	0	0	0	224.0	224.0	0.0	Device not used in 1979
19	M	0	0	0	0	40.0	0.0	40.0	
21	M	0	0	0	1/1	-	-	-	1979 data unavailable
24	C	1	0	1	1/3	94.0	79.5	14.5	SIC code incorrect
25	M	0	0	0	0	45.0	30.0	15.0	SIC code incorrect
26	C	0	0	1	0	37.9	38.4	-0.5	SIC code incorrect
27	I	7	0	0	1/7	56.0	56.5	-0.5	Device/process classification needs major revision
29	M	0	0	0	0	27.8	25.4	2.4	
30	C	0	0	0	0	34.0	29.6	4.4	
32	C	0	0	0	2/9	125.0	124.4	0.6	Facility changed name
34	C	0	0	0	1/1	96.0	96.3	-0.3	
37	C	0	3/6	0	0	23.1	1.3	21.8	
45	C	0	0	0	3/6	31.0	37.5	-6.5	
50	C	0	0	0	0	57.0	54.1	2.9	SIC code incorrect
51	I	3	1/3	3	1/3	96.0	96.3	-0.3	SIC code incorrect
52	C	0	0	0	1/3	25.0	22.7	2.3	No organic solvents used

Table 4.1-2

SUMMARY OF DISCREPANCIES FOUND BY EDS VERIFICATION SURVEY
(Continued)

Survey Code No.	Site Address[a]	No. of Devices[b]		No. of Processes[b]		Solvent Emissions (tons/yr)			Comments
		Missing	Incorrect	Missing	Incorrect	EDS	SAI	Diff.	
58	C	0	0	0	0	48.0	47.7	0.3	SIC code incorrect
60	C	-	-	-	-	-	-	-	1979 data unavailable
62	I	0	0	6	6/7	326.0	317.8	8.2	
66	C	0	1/1	0	1/1	39.0	35.2	3.8	Control device absent from EDS
81	C	0	1	0	1/2	100.0	7.8	92.2	
82	C	0	0	0	1/6	45.8	44.7	1.1	
85	C	2	1	4	1/4	43.0	48.6	-5.6	
86	M	-	-	-	-	-	-	-	Questionnaire not returned
87	C	3	0	8	0	318.1	260.9	57.2	Device/process classification needs major revision
88	M	0	0	1	1/2	58.5	392.6	-334.1	
89	C	0	0	0	0	20.0	3.9	16.1	
90	C	0	0	0	0	37.0	37.2	-0.2	SIC code incorrect
93	I	0	0	0	0	23.0	24.2	-1.2	SIC code incorrect,
94	C	0	0	0	0	-	-	-	No data supplied by firm
98	C	0	1	0	2/2	22.0	0.0	22.0	No organic solvent used
99	C	0	0	0	0	62.0	60.8	1.2	
100	C	0	0	1	1/2	-	-	-	1979 data unavailable
103	C	0	0	0	0	275.0	145.9	129.1	
108	M	0	3/3	0	3/3	23.7	59.8	-36.1	SIC code incorrect
109	C	1	0	1	0	107.0	59.5	47.5	SIC code incorrect
110	C	0	0	0	0	81.0	30.0	51.0	SIC code incorrect

Table 4.1-2

SUMMARY OF DISCREPANCIES FOUND BY EDS VERIFICATION SURVEY
(Continued)

Survey Code No.	Site Address[a]	No. of Devices[b] Missing	Incorrect	No. of Processes[b] Missing	Incorrect	Solvent Emissions (tons/yr) EDS	SAI	Diff.	Comments
111	C	0	0	0	0	-	-	-	1979 data unavailable
113	C	0	1/4	0	1/6	-	-	-	1979 data unavailable
114	C	1	0	1	0	146.9	122.1	24.8	
119	C	1	4/9	1	4/9	92.0	92.1	-0.1	
120	C	0	0	9	0	75.0	75.2	-0.2	SCC codes too general

a Key: C = correct, I = incorrect or incomplete, M = missing.
b Incorrect devices or processes are reported as (number incorrect)/(number originally in EDS).

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these sources easily. As seen in Table 4.1-2, facility addresses were missing, incorrect or incomplete for 12 (24 percent) of the respondents. Of the 121 facilities in the original set, at least 25 (21 percent) had deficient addresses. The proportion of facilities with deficient addresses in San Diego County is significantly higher than expected, while that for the South Coast Air Basin is lower (x^2 = 15.793, d.f. = 3); given the small sample size, however, generalizations to the entire EDS are not warranted.

Standard Industrial Classification (SIC) Codes

SIC codes, as recorded in the EDS, were incorrect for 12 of the facilities who responded to our questionnaire. (One of these did not provide any other information and is thus not represented in Table 4.1-2.) Table 4.1-3 shows the incorrect SIC codes and the correct ones, as reported by the facilities or determined by us from their descriptions. In only two cases was the code correct to three digits. For Survey No. 110, the error was probably one of transposition when the code was entered into the computer. Our experience in keypunching thousands of SIC codes is that errors of this type are very common. Since the SIC code is an element of the definition of the ARB's Category of Emission Source (CES) codes, the CES numbers for all processes corresponding to the facilities whose SIC codes are in error are also incorrect. In our case 33 CES numbers must be changed. For example, the open-top vapor degreasers (using perchloroethylene) at Firm No. 51 must be reclassified from CES 63180 to 22988.

Device and Process Classification

Of the 49 responding firms, 9 had devices which were not recorded in the EDS; 20 devices were missing. More than one quarter of the facilities reported processes in addition to those recorded in the EDS; 38 processes were thus unaccounted for. At least some of these absences may have been due to use of overly flexible, or at least quite arbitrary, classification criteria by the local APCDs. For example, in many cases facilities having three or four spray booths are recorded as having one device; the booths are considered in the aggregate. For other facilities, the APCD considers each booth to be a separate device.

Table 4.1-3

INCORRECT SIC CODES IN THE EDS VERIFICATION SURVEY SAMPLE

Survey Code No.	SIC Code in EDS	Description	Correct Code	Description
12	3674	Semiconductors and related devices	3679	Electronic component mfgrs.
24	5111	Printing and writing paper wholesaler	2643	Bag manufacturers
25	3444	Sheet metal work mfrs.	3452	Bolt, nut, screw, rivet and washer mfrs.
26	2653	Corrugated and solid fiber box mfrs.	2651	Folding paperboard box mfrs.
50	2521	Wood office furniture manufacturing	2511	Wood household furniture
51	3634	Electric houseware and fan mfrs.	3471	Plating and polishing plants
58	3542	Machine tool, metal forming types	3479	Metal coating and allied service
93	3364	(Nonexistent code)	3679	Electronic component mfrs.
94	1629	Heavy construction contractors	3732	Boat building and repairing
107	7699	Repair services, not elsewhere classified	7216	Dry cleaning plants
108	3444	Sheet metal work mfrs.	3452	Bolt, nut screw, rivet and washer mfrs.
110	3714	Motor vehicle parts and accessories	3471	Plating and polishing plants

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Among the responding facilties, 20 (41 percent) had processes which were incorrectly reported in the EDS; 35 processes were in error. The most common types of errors in classifying devices and processes were:

- Designation of conveyorized degreasers as open-top vapor degreasers;

- Ending SCC numbers with 99 ("not classified") when an appropriate classification is available;

- Inclusion of a solvent (e.g. MEK) with thinners when it is actually used for cleaning;

- Designation of styrene and other cross-linking agents in polyester resin use as solvents; this problem was addressed in our study of the California polyester resin industry (Rogozen, 1982);

- Inclusion of devices and/or processes which never existed or which were taken out of service before 1979; and

- Improper designation of coating type (e.g. enamel for lacquer, or paint for adhesives)

Although source classification codes and CES numbers are available for indicating emissions of individual solvents, they appear to be used only rarely. Many firms identify their solvents on the SCAQMD's Form B-3, yet the District does not supply the speciated information to the ARB.

Except for cases of devices and processes which were improperly included in or omitted from the EDS, these misclassification problems are not likely to lead to serious errors in estimation of TOG emissions at the county and state levels. They do, however, make it extremely difficult to obtain useful information on emissions of individual solvents or on emissions from particular industries or processes.

Emission Controls

Very few of the facilities in the survey have devices for controlling volatile organic compound (VOC) emissions. The only serious errors in the EDS records for the responding firms were the omissions of an activated carbon adsorption system from Firm No. 81 and a direct-flame afterburner from

Firm No. 114. Omission of the carbon adsorption system resulted in an over-estimate of 92.2 tons/year for the firm. If omission of the afterburner from Firm 114's records had been the only problem in that case, the EDS would have overstated the facility's solvent emissions by 72.1 tons, according to our calculations. (See Appendix B.) However, the EDS also failed to include 47.3 tons of emissions from cleanup solvent use. Thus the overestimate was 24.8 tons.

Emission Factor Determination

A potentially important finding of this survey was that the great majority of people who supply annual data to the local districts have a poor understanding of how emissions are estimated, and what information is required of them. As mentioned above, we received numerous requests for explanation of our emission factor questions. Many respondents apparently believed that emissions and emission factors were the same thing. In many cases, the person filling out the district forms has little or no technical training. Four of the respondents refer the district forms to their out-of-state headquarters, while one uses a local consultant.

Of the 36 facilities who reported how emissions were customarily estimated, 24 said that they calculated net volumetric use of solvents and solvent-containing formulations and multiplied these by the emission factors supplied by the SCAQMD. Eleven firms performed detailed mass balances, using product-specific data. Only one of the respondents reported having measured emissions directly.

Given the heavy reliance, at least in the South Coast Air Basin, upon emission factors supplied by the local air pollution control district, we compared these factors with the densities of the corresponding solvents, using data from solvent manufacturers' literature. Table 4.1-4 shows the comparisons for the major solvents. The SCAQMD emission factors are all within five percent of the commercial solvent values; most are within one percent. As will be discussed in Section 4.2.4, differences between actual emission factors for certain coatings and those suggested by the SCAQMD are greater.

Table 4.1-4

COMPARISON OF SCAQMD ORGANIC SOLVENT EMISSION FACTORS
WITH DENSITIES OF COMMERCIAL-GRADE SOLVENTS

Solvent	SCAQMD Emission Factor (lb/gal)	Commercial Density (lb/gal)		Percent Variation
		Low	High	
Acetone	6.6	6.59	6.59	0.15
Benzene	7.3	7.35	7.36	-0.68 to -0.82
Cellosolve acetate	8.1	8.10	8.12	0 to -0.25
Dimethyl formamide	7.9	7.86	7.86	0.51
Ethylene glycol monobutyl ether	7.5	7.51	7.51	-0.13
Ethylene glycol monoethyl ether	7.7	7.76	7.74	-0.52 to -0.72
Freon 113	13.0	13.06	13.06	-0.45
Furfuryl alcohol	9.4	9.0	9.0	4.4
Hexylene glycol	7.7	7.68	7.68	0.26
Hexane	5.5	5.56	5.61	-1.1 to -2.0
Isopropyl alcohol	6.6	6.55	6.55	0.76
kerosene	7.0	6.83	6.83	2.5
Lactol Spirits	6.3	6.15	6.15	2.4
Methanol	6.6	6.60	6.60	0
Methylene chloride	11.2	10.98	11.0	1.8 to 2.0
Methyl ethyl ketone	6.7	6.71	6.71	-0.15
Mineral spirits	6.5	6.53	6.55	-0.46 to -0.76
Naphtha	6.3	6.12	6.12	2.9
1,1,1-trichloroethane	11.1	10.76	10.8	1.8 to 3.2
Perchloroethylene	13.5	13.46	13.5	0 to 0.30
Toluene	7.2	7.25	7.28	1.1
VM&P naphtha	6.3	6.27	6.27	0.48
Var Sol #1	6.5	6.60	6.60	-1.5
Xylene	7.2	7.24	7.26	-0.55 to -0.83

Emissions

For facilities who provided us with sufficient information, we made an independent estimate of TOG emissions; in all other cases, we considered the data supplied by the facility to the local APCD to be "correct." As seen in Table 4.1-2, discrepancies between our estimates (or facility-reported estimates) and corresponding values in the EDS were found in almost all cases. Absolute discrepancies ranged from 0 to 335.0 tons/year per facility. Since many of the data were provided by the respondents to one or two significant figures (e.g. 15,000 gallons of coating), discrepancies of less than 1 ton/year are probably insignificant. In 30 of the 41 cases for which 1979 data were available, the absolute discrepancy was greater than this value. Figure 4.1-3 shows the cumulative distributions of positive and negative errors, for which the geometric means are 11.1 and 1.8 tons/year respectively. Positive errors, i.e. those resulting when the EDS value exceeds our estimate, outnumber negative errors. For the facilities for which we could make an emission estimate, the EDS reports TOG emissions of 4,135.5 tons/year. Our estimate of emissions for these same firms is 3,642.9 tons/year. If our estimate is taken to be correct, then the net error for our sample is 491.6 tons/year, or 13.5 percent.

Changes in point source organic solvent emissions for seven counties are summarized in Table 4.1-5. Since the error for one facility increases Riverside County's organic solvent emissions by 20.9 percent, we recommend an independent verification of the error by the SCAQMD. Percent changes for other counties are fairly small.

The largest errors in the sample were the result of:

●   Omission of major devices and/or processes from the EDS,

●   Inclusion of devices which are no longer in service, and

●   Failure to take into account emission control equipment.

In four cases, emissions data reported in the EDS were quite different from what the facility reported to the local APCD. Before the survey, it was thought that emissions reported for firms whose origin was the SCAQMD's EDP

Table 4.1-5

RECOMMENDED CHANGES IN EDS POINT SOURCE EMISSIONS BY COUNTY
(All emissions in tons/year)

County	Original Total in EDS	Change Resulting From SAI Survey	New Total Emissions	Percent Change
Los Angeles	47,373	-415.3	46,957.7	-0.88
Orange	11,102	-4.4	11,097.6	-0.04
Riverside	1,599	+334.1	1,933.1	+20.9
Sacramento	2,128	-12.6	2,115.4	-0.59
San Bernardino	3,573	-47.3	3,525.7	-1.32
San Diego	11,427	-378.7	11,048.3	-3.31
Santa Clara	4,390	+32.6	4,422.6	+0.74
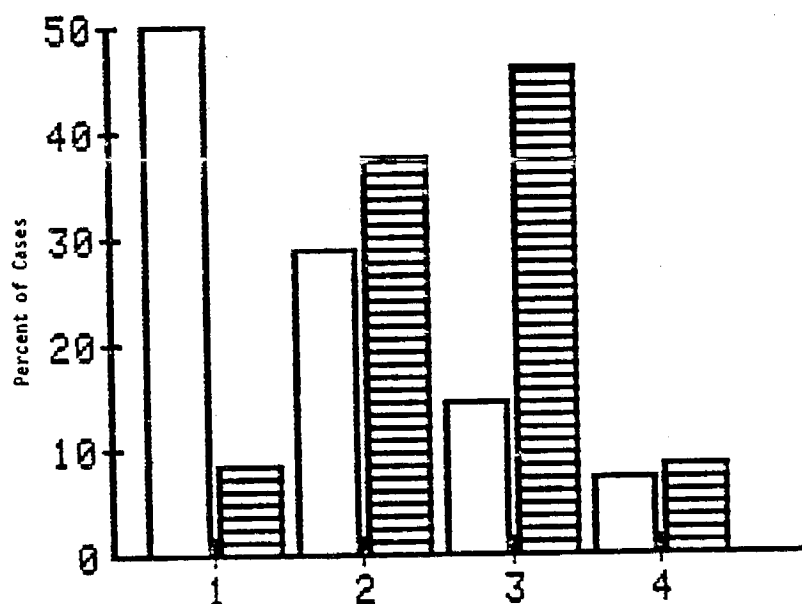
KEY
1 = 0.1 to 1 ton/year
2 = 1 to 10 tons/year
3 = 10 to 100 tons/year
4 = 100 to 1000 tons/year

Figure 4.1-3. Distribution of Negative (Outlined Bars) and Positive (Shaded Bars) Discrepancies between Emissions Reported by Survey Respondents and Those Recorded in the EDS.

file (see Section 3.1) would be more likely to be in error than those for firms whose data are updated annually. Only three surveys were returned by the EDP facilties in our sample set; of these one had an emissions error four standard deviations from the arithmetic mean for the entire survey, but the other two had errors within one standard deviation of the mean.

4.1.2.2   Errors in Universal Transverse Mercator (UTM) Coordinates

Modeling of air pollution from multiple sources requires accurate spatial representation of the sources. The photochemical models used for projecting air quality trends in the major air basins depend upon a grid system whose coordinates correspond to discrete one- or five-km intervals of the UTM system. Since a point source's UTM coordinates determine in which grid cell it lies, it is essential that they be accurate. According to an ARB modeling specialist, an error of ± 0.5 km in location would be cause for concern in some models (Allen, 1982).

Discussions with the South Coast Air Quality Management District led us to believe that the potential for errors in UTM coordinate designation was significant. The locations of sources in the SCAQMD's emission inventories were formerly designated by a coordinate system consisting of one-mile-square cells. When it became necessary to convert locations to the UTM system, the UTM coordinates for each source were arbitrarily defined as the center of the corresponding one-mile square, no matter where the source actually was in the square (Thomas, 1982). The District then used a computer program to assign UTM coordinates to each point source (Grisinger, 1981).

Figure 4.1-4 shows two ways by which this conversion may have led to incorrect placement within 5-km cells used for modeling. The large, solid-outlined squares are 5 km x 5 km grid cells. (One-km subdivisions are included to show the scale.) Dashed lines denote the SCAQMD's original one-mile square cells. A source at point A would have been considered by the District to be at the center of the one-mile cell, and therefore would now be considered to be in the 5-km cell shown. Meanwhile, a source at point B actually lies within the 5-km cell. However, since the SCAQMD assumed it to be at the
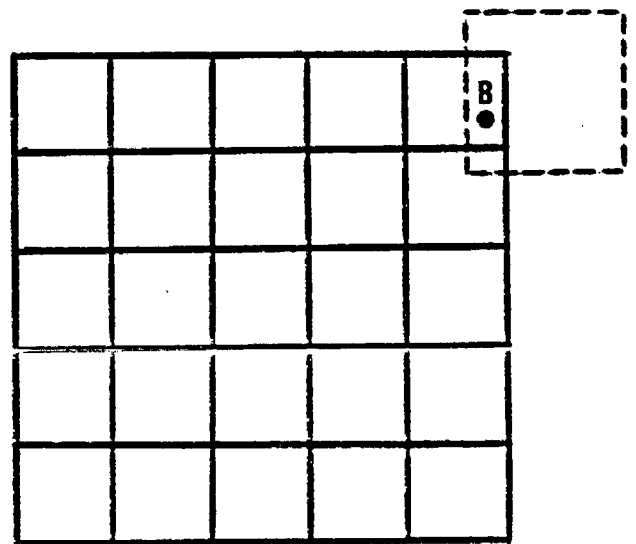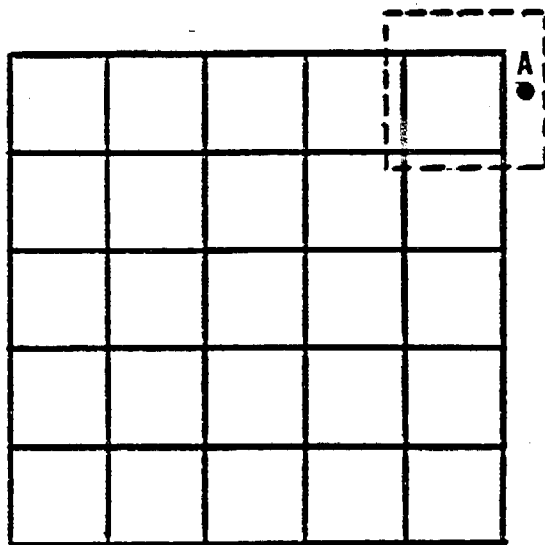
Figure 4.1-4. Examples of Location Errors Due to Method of
Converting From SCAQMD System to UTM Coordinates.

center of the one-mile cell, which lies outside the 5-km cell, the EDS location would be in error.

UTM coordinates for 27 of the facilities in our EDS verification survey were determined by the method outlined above. Errors in the east and north UTM coordinates, e_E and e_N, were defined as follows:

$$e_E = E_M - E_R \qquad (4.1\text{-}1)$$

$$e_N = N_M - N_R \qquad (4.1\text{-}2)$$

$$E = (e_E{}^2 + e_N{}^2)^{0.5} \qquad (4.1\text{-}3)$$

where E and N are the east and north UTM coordinates, and the subscripts M and R denote values measured by SAI and reported by the EDS, respectively. Table 4.1-6 shows the results of our analysis. All but two of the facilities' coordinates were in error by more than the 0.1 km measurement error mentioned above. In 13 cases (48 percent), the total displacement error exceeds the 0.5 km of concern to modelers. One third of the facilities' UTM coordinates are in error by more than 1 km. The highest error was for facility 37-182 in San Diego County, whose UTM east and north coordinates were incorrect by 2.0 and 3.4 km, respectively.

4.2   EVALUATION OF EMISSION ESTIMATION METHODS

4.2.1   Dry Cleaning

Dry cleaning is a waterless process in which clothes are cleaned with an organic solvent rather than with soap and water. Operations vary in size, type of service and type of solvent used. The three principal types of dry cleaning establishments are coin operated, commercial and industrial.

4.2.1.1   Solvents Used

Solvent types presently used in the dry cleaning industry include petroleum solvents (e.g. Stoddard and 140-F), which are mixtures of paraffins and aromatic hydrocarbons; perchloroethylene and trichlorotrifluoroethane (F-113). Table 4.2-1 provides an estimate of the distribution of facilities

Table 4.1-6

RESULTS OF CHECK ON UTM COORDINATES

County	District ID No.	UTM East EDS	UTM East SAI	Diff.	UTM North EDS	UTM North SAI	Diff.	e
Los Angeles	796	394.9	394.6	0.3	3778.6	3777.5	1.1	1.1
	1146	369.1	368.7	0.4	3756.2	3756.1	0.1	0.4
	1264	396.3	396.4	-0.1	3760.8	3760.1	0.7	0.7
	1850	380.2	379.1	1.1	3749.7	3748.7	1.0	1.5
	1960	386.8	385.9	0.9	3764.1	3762.7	1.4	1.7
	2896	389.9	389.9	0.0	3757.6	3757.7	-0.1	0.1
	3255	407.6	406.8	0.8	3770.4	3769.5	0.9	1.2
	3527	388.4	388.1	0.3	3772.2	3772.1	0.1	0.3
	3531	383.5	382.3	1.2	3752.9	3752.8	0.1	1.2
	5082	383.5	383.6	-0.1	3760.9	3761.1	-0.2	0.2
	5296	394.7	394.8	-0.1	3760.8	3761.0	-0.2	0.2
	5535	381.9	382.1	-0.2	3752.9	3753.1	-0.2	0.3
	6044	355.0	354.6	0.4	3790.3	3789.9	0.4	0.6
	27252016	366.2	365.8	0.4	3798.2	3796.8	1.4	1.5
	42230032	389.9	389.5	0.4	3762.5	3762.3	0.2	0.4
	43226051	391.5	391.2	0.3	3756.0	3755.7	0.3	0.4
Orange	35	421.7	422.0	-0.3	3729.9	3729.9	0.0	0.3
	45	421.6	420.8	0.8	3726.7	3726.0	0.7	1.1
	159	415.3	415.1	0.2	3728.3	3728.7	-0.4	0.4
	341	412.3	412.5	-0.2	3754.2	3753.6	0.6	0.6
	564	417.0	416.3	0.7	3746.1	3746.5	-0.4	0.8
	1802	421.7	421.9	-0.2	3729.9	3729.5	0.4	0.4
	1931	407.3	407.1	0.2	3734.9	3734.8	0.1	0.2
Riverside	85227005	458.7	457.2	1.5	3757.0	3758.0	-1.0	1.8[a]
San Diego	182	471.6	469.6	2.0	3662.2	3665.0	-2.8	3.4
	251	484.7	484.8	-0.1	3637.6	3637.5	0.1	0.1
Santa Clara	18	601.7	601.6	0.1	4129.5	4129.3	0.2	0.2

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[a] Large error may be due to lack of precise knowledge of emission point.

Table 4.2-1

NATIONAL PATTERN OF USE OF MAJOR DRY CLEANING SOLVENTS,
BY TYPE OF ESTABLISHMENT

SIC Code	Description	Percent of Establishments Using Solvents		
		Perc	Petroleum Solvent	Freon-113[a]
7215	Coin-operated	97	0	3
7216	Commercial	73	24	3
7218	Industrial	50	50	0

Source: TRW, 1980.

[a] Freon-113 is a trademark of E.I du Pont de Nemours Company.

using these solvents among types of dry-cleaning establishments, nationwide. Perchloroethylene ("perc") is used in approximately 80 to 90 percent of all dry cleaning establishments and constitutes about 70 percent of all cleaning solvent consumed. Almost all other establishments use petroleum solvents. Fluorocarbons represent only a small percentage of dry cleaning solvent use.

According to a dry cleaning industry trade association, the use of F-113 is not expected to increase markedly in the near future because of its poor cleaning power (Laumann, 1981). Fire prevention regulations will prevent a major increase in the use of petroleum solvents, which are highly combustible. The use of perchloroethylene is expected to increase relative to other cleaning solvents because of its superior cleaning power and low flammability (Laumann, 1981).

4.2.1.2   Emission Estimation Methods

In California, all dry cleaning facilities having emissions exceeding 20 tons per year and many having lower emissions are treated in the EDS as point sources. The South Coast Air Quality Management District (SCAQMD) has included permit file information on many small dry cleaning plants in its data submissions to the ARB (Thomas, 1982). The Fresno County Air Pollution Control District is setting up an inventory of all permitted dry cleaning facilities in its jurisdiction; point source emission data will eventually be incorporated in the EDS (Tollstrup, 1982). Smaller facilities are aggregated in the EDS as area sources. We therefore reviewed both point and area source emission estimation methodologies. An alternative approach for estimating area source emissions is presented below.

Point Source Emissions

The most common basis for point source emission estimates for dry cleaning facilities are mass of clothes cleaned and mass of cleaning solvent used. Table 4.2-2 shows a set of emission factors of the first type, as suggested in a supplement to AP-42 (Sercer, 1977). These factors are rated "above average" by EPA; they are presumably based upon some field data, including material balances, although we could not verify their sources. Emission

Table 4.2-2

SOLVENT LOSS EMISSION FACTORS FOR DRY CLEANING OPERATIONS

Solvent type (Process used)	Source	Emission rate[a] Typical systems lb/100 lb (kg/100 kg)	Well-controlled system lb/100 lb (kg/100 kg)
Petroleum (transfer process)	washer/dryer[f] filer disposal	18	2[b]
	uncooked (drained) centrifuged	5	
	still residue disposal	2	0.5 - 1
	miscellaneous[c]	3	1
Perchloroethylene washer/dryer/ still/muck cooker (transfer process)	filter disposal	8[d]	0.3[b]
	uncooked muck	14	
	cooked muck	1.3	0.4 - 1.3
	cartridge filter	1.1	0.5 - 1.1
	still residue disposal	1.6	0.5 - 1.6
	miscellaneous[c]	1.5	1
Trichlorotri- fluoroethane (dry-to-dry process)	washer/dryer/still[e] cartridge filter disposal	0	0
		1	1
	still residue disposal	0.5	0.5
	miscellaneous[c]	1 - 3	1 - 3

Source: Sercer, 1977.

[a] Units are in terms of weight of solvent per weight of clothes cleaned (capacity x loads). Emissions may be estimated on an alternative basis by determining the amount of solvent consumed. Assuming that all solvent input to dry cleaning operations is eventually evaporated to the atmosphere, an emission factor of 2000 lb/ton of solvent consumed can be applied.

[b] Emissions from the washer, dryer, still, and muck cooker are collectively passed through a carbon adsorber.

[c] Miscellaneous sources include fugitive emissions from flanges, pumps, pipes, storage tanks, fixed losses (for example, opening and closing the dryer), etc.

[d] Uncontrolled emissions from the washer, dryer, still, and muck cooker average about 8 lb/100 lb (8 kg/100 kg). Roughly 15% off the solvent emitted comes from the washer, 75% from the dryer, and 5% from both the still and the muck cooker.

[e] Emission factors are based on the typical refrigeration system installed in fluorocarbon plants.

[f] Different materials in the wash retain varying amounts of solvent (synthetic: 10 kg/100 kg, cotton: 20 kg/100 Kg, leather: 40 kg/100 kg).

factors for perchloroethylene dry cleaning in Sercer (1977) were compiled from Kleeberg and Wright (1978); these are based upon industry estimates (Fisher, 1975) and EPA material balance tests.

Use of mass of clothes cleaned as a basis for estimating emissions presents problems. Information of that type is not readily obtainable from dry cleaning plant operators. Furthermore, as noted in a footnote to Sercer's original table (in AP-42), different materials in the wash retain varying amounts of solvent. Thus the uncertainty in estimates based upon mass of clothes washed is considerable. A check of the dry cleaning facilities included in our EDS verification survey sample showed that emissions in six cases were apparently estimated on this basis. However, we learned from discussions with the SCAQMD that clothes-based emission factors were back-calculated from solvent use data, since the old EPA source classification codes for dry cleaning required use of those factors (Maloney, 1982).

The SCAQMD, BAAQMD and most other air pollution control agencies now collect data on solvent use from dry cleaning plants. The emission factor is 2000 pounds per ton of solvent used, i.e. 100 percent, unless emissions are controlled.

Area Sources

Dry cleaning facilities emitting less than 25 tons/year are generally classified as area sources in the EDS, although, as noted above, many of these smaller facilities are included in the EDS as point sources. The EPA (Lamason and Lahre, 1980) recommends that VOC area source emissions from dry cleaning be estimated by use of emission factors of 1.2 and 0.3 lb/year per capita, respectively, for commercial and coin-operated plants. (Industrial plants, being larger, would generally be treated as point sources). These per capita emission factors are based upon unpublished EPA data and could not be verified.

The ARB also bases its dry cleaning emission estimates upon population, although it makes its assumptions explicit (Wong and Ipps, 1982). First, nationwide consumption of perchloroethylene in dry cleaning in 1978 was

found to be 160 million kg (353 million lb). A one-percent per year growth rate was then assumed. Petroleum solvent consumption for the base year 1975 was assumed to equal an EPA emissions estimate of 68 million kg. The growth rate for petroleum solvent consumption was also estimated at one percent per year. National totals are then apportioned to California on the basis of the ratio of state to U.S. population. County emissions are calculated on the basis of the ratio of county to state populations.

One potential source of error in this methodology is the assumption regarding total national perchloroethylene consumption. According to the Textile Care Allied Trades Association (formerly the Laundry and Cleaners Allied Trade Association), which supplied the 1978 estimate, U.S. use of perchloroethylene in dry cleaning was 308.2 million lb in 1980 (Knipe, 1981). Thus use of this solvent decreased by 12.7 percent over the two years. Assuming that annual rate of the decrease was constant, national perchloroethylene use would have been 330.5 million lb in 1979, rather than the ARB's projection of 356.3 million lb. Another problem is that the assumption that dry cleaning solvent emissions are directly proportional to population may not necessarily be valid.

Table 4.2-3 shows combined synthetic and non-synthetic solvent emissions from dry cleaning in the San Joaquin Valley, as estimated by the method of Wong and Ipps (1982) and determined by a comprehensive survey by the Fresno County Air Pollution Control District (Roddy, 1981). The estimated emissions are twice those accounted for by the District. We performed numerous regression analyses to ascertain a relationship between county emissions and population, using the San Joaquin Valley data. The best fit was obtained with a log-linear regression:

$$E = \exp [4.362 + 0.00808 \, (P - 193.85)] \qquad (4.2-1)$$

where E is annual emission (tons) and P is the county population in thousands. Figure 4.2-1 shows the closeness of the fit.

Review of RAMIS reports provided to SAI by the Stationary Source Control Division showed that about 37 percent of the dry cleaning area source

Table 4.2-3

DRY CLEANING EMISSIONS IN THE SAN JOAQUIN VALLEY, 1979

| County | 1979 VOC Emission (tons) | | 1980 Urban Population[c] (1000) |
	ARB Estimate[a]	FCAPCD Survey[b]	
Fresno	542	468	403.1
Kern	423	212	330.5
Kings	79	28	48.9
Madera	66	22	30.1
Merced	142	22	83.8
San Joaquin	359	150	286.0
Stanislaus	281	97	215.2
Tulare	265	75	153.2
Totals	2,157	1,074	1,550.8

[a] Wong and Ipps (1982)

[b] Data provided to SAI by Fresno County Air Pollution Control District (Roddy, 1981).

[c] U.S. Bureau of the Census.
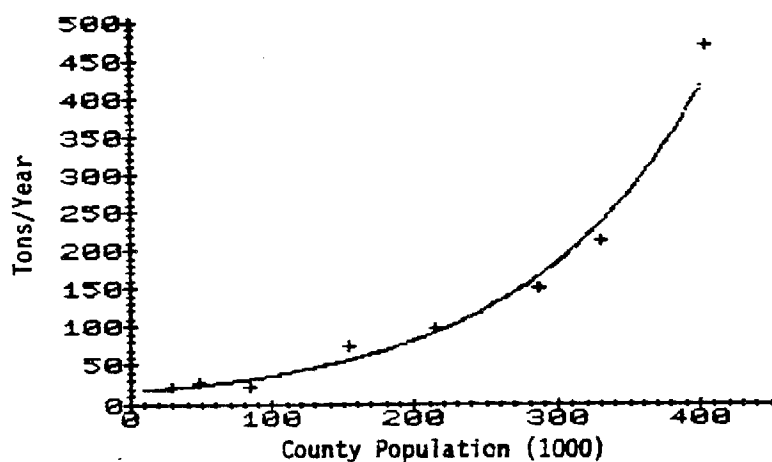
Figure 4.2-1. Regression Curve for Dry Cleaning Emissions vs. Population in the San Joaquin Valley.

emissions were calculated using the method of Wong and Ipps (1982). We recommend that Equation 4.2-1 be used for those counties for which direct survey information is unavailable. Our method does not assume any relationship between California emissions and national solvent use figures and is thus subject to less uncertainty.

Among the counties for which the current ARB methodology is still used are Monterey, San Luis Obispo, Santa Cruz, Shasta, and Yolo, whose combined dry cleaning area source emissions are 916 tons. Applying Equation 4.2-1 to these counties, we estimate dry cleaning area source emissions of only 262 tons. We recommend that the APCD responsible for these counties conduct surveys to determine where between these estimates the true emission values lie. We also recommend that special attention be paid to San Diego County, whose 1,997 tons of dry cleaning emissions were apparently estimated by the ARB method. Equation 4.2-1 cannot be used in this case, since the county's population lies outside the range used in the regression analysis.

Although the foregoing implies that the EDS overpredicts dry cleaning emissions, some of the findings from our market balance study lead to an opposite conclusion. As will be discussed in Section 5.2, the Halogenated Solvents Industry Alliance reported to us that 63.9 million lb (31,950 tons) of perchloroethylene were sold to California consumers and distributors in 1980. From our survey of direct industrial consumption (discussed in Section 5.3), we estimate that between 5,396 and 8,000 tons of perchloroethylene were used in processes other than dry cleaning in the same year. The amount of perchloroethylene left over for dry cleaning in California would therefore be 23,950 to 26,554 tons. We could not estimate Stoddard solvent use in dry cleaning, since we were unable to obtain an estimate of total sales to California. Dry cleaning emissions would be higher than 23,950 to 26,554 tons, by an unknown amount. The EDS reports total emissions of only 21,180 tons. From this we would conclude that the EDS under-predicts dry cleaning emissions.

4.2.2   Degreasing

Solvent metal cleaning or degreasing operations employ nonaqueous solvents to remove soils from the surface of metal articles which are to be

electroplated, painted, repaired, inspected, assembled, or machined. Degreasing operations may be carried out in a wide variety of industries, including (1) metal working facilities (e.g., automotive, electronics, appliances, furniture, jewelry, plumbing, aircraft, refrigeration; (2) non-metal working facilities (printing, chemicals, plastics, rubber, textiles, glass, paper, electric power; (3) maintenance and cleaning operations; and (4) repair shops. The number of companies routinely using solvent metal cleaning operations probably exceeds one million (Bollinger and Shumaker, 1977). Table 4.2-4 gives the relevant SIC codes for metal cleaning industries. Large facilities may have over 100 separate degreasing operations at one location.

4.2.2.1   Source Description

The three types of degreasers are small cold cleaners, open top vapor degreasers, and conveyorized degreasers. According to recent estimates, about 1,300,000 small cold cleaning units operate in the United States (Bollinger and Shumaker, 1977). Seventy percent of these units are applied in maintenance of service operations, including service stations, auto dealerships, and miscellaneous repair stations, while the remaining 30 percent are used in manufacturing. A typical cold cleaning unit emits approximately one-third metric ton of VOC per year (Lamason and Lahre, 1980). In contrast, typical open top vapor degreasers and conveyorized degreasing units emit, on average, 10 and 27 metric tons of VOC per year, respectively. These larger units are commonly used in the metal working industry.

Solvents Used

A broad spectrum of organic solvents is available for degreasing operations. Table 4.2-5 shows national degreasing solvent consumption for 1974. These data have undoubtedly changed between 1974 and 1980. Similar figures are not available for 1980, but Table 4.2-6 gives SAI's estimates of national and state use for particular solvents. Trichloroethylene use, for example, has been sharply curtailed due to regulatory restrictions. Use of less toxic chlorinated solvents such as 1,1,1-trichloroethane has increased proportionately. Choices among solvents are based on the solubility of the soil, toxicity, flammability, evaporation rate, effect on non-metal portions

Table 4.2-4

INDUSTRIES WHICH USE SOLVENT METAL CLEANING

SIC Code (3 digit codes)	Description
25 (254, 259)	Furnitures and fixtures
33 (332, 334, 335, 336, 339)	Primary metal industries
34 (342-349)	Fabricated metal products
35 (351-359)	Machinery, except electrical
36 (361-364, 366, 367, 369)	Electric and electronic equipment
37 (371, 372, 376, 379)	Transportation equipment
38 (381, 382)	Instruments and related products
39	Miscellaneous manufacturing industries
45 (458)	Air Transportation
75 (753)	Automotive repair shops

Source: Anon. (1979)

Table 4.2-5

NATIONAL DEGREASING SOLVENT CONSUMPTION (1974)

Solvent Type	Solvent Consumption (10^3 metric tons)		
	Cold Cleaning	Vapor Degreasing	All Degreasing
Halogenated Hydrocarbons:			
trichloroethylene (being replaced by 1,1,1 trichloroethane)	25	128	153
1,1,1 trichloroethane	82	80	162
perchloroethylene	13	41	54
methylene chloride	23	7	30
trichlorotrifluoroethane	10	20	30
	153	276	429
Aromatic Hydrocarbons:			
benzene	7		
toluene	14		
xylene	12		
heavy aromatics	12		
	45	0	45
Aliphatic Hydrocarbons:[a]			
heptane kerosene stoddard solvent mineral spirits cyclohexane	1		
	223	0	223
Ketones:			
acetone	10		
methyl ethyl ketone	8		
	18	0	18

Table 4.2-5 (Continued)

NATIONAL DEGREASING SOLVENT CONSUMPTION (1974)

Solvent Type	Solvent Consumption (10^3 metric tons)		
	Cold Cleaning	Vapor Degreasing	All Degreasing
Alcohols:			
butanol	5		
ethanol			
isopropanol			
methanol			
	5	0	5
Ethers:			
ethylene glycol monobutyl ether			
ethylene glycol monoethyl ether			
	6	0	6
Total Solvents:	450*	276**	726
Range of Accuracy:	(+ 125)	(+ 25)	(+ 145)

Source: Bollinger and Shumaker, 1977
* Includes 25,000 metric tons from non-boiling conveyorized degreasers
** Includes 75,000 metric tons from conveyorized vapor degreasers
[a] Blanks signify no data available on individual solvent totals.

Table 4.2-6

SAI ESTIMATE OF DEGREASING SOLVENT USE FOR PARTICULAR SPECIES (1980)[a]

Solvent Type	Solvent Availability			
	U.S. Total		California Total	
	(10^6 lbs)	(10^3 MT)[b]	(10^6 lbs)	(10^3 MT)
Trichloroethylene	183.85	83.39	23.05	10.46
Perchloroethylene	129.0	58.51	16.18	7.34
Methylene Chloride	113.98	51.70	14.29	6.48
1,1,1 Trichloroethane	449.81	204.03	56.41	25.59
Totals	876.64	397.63	109.93	49.87

[a] For background on methodology see section 5.4.
[b] MT = metric ton.

of the part cleaned and numerous other properties. In cold cleaning operations, all types of solvents are used; the choice of a solvent depends on the type of parts to be cleaned. Open top vapor and conveyorized degreasers use halogenated solvents because vapors are non-flammable and much heavier than air.

Cold Cleaners

Cold cleaner operations include spraying, brushing, flushing and immersions. The solvent is occasionally heated in cold cleaners but always remains well below its boiling point. Cold cleaners are estimated to result in the largest total emission of the three categories of degreasers, primarily because much of the disposed waste solvent is allowed to evaporate.

The two basic types of cold cleaners are maintenance cleaners and manufacturing cleaners. Maintenance cleaners are designed principally for automotive and general plant maintenance cleaning. Manufacturing cold cleaners are fewer in number than maintenance cleaners but tend to emit more solvent per unit because of larger size and work load. Manufacturing cleaners use a wide variety of solvents, whereas maintenance cleaners use mainly other petroleum solvents such as mineral spirits and petroleum distillates.

In a typical cold cleaner, the dirty parts are cleaned manually by spraying and by soaking in the dip tank. The solvent in the dip tank is often agitated to enhance cleaning action. After cleaning, the basket of cleaned parts may be drained on an external drainage rack which routes the drained solvent back into the cleaner. The tank is intended to be closed whenever parts are not being handled in the cleaner.

Open Top Vapor Degreasers

Vapor degreasers clean by the condensation of hot solvent on colder metal parts. Open top vapor degreasers are batch loaded. The solvent vapors condense on the parts to be cleaned until the temperature of the parts approach the boiling point of the solvent. The condensing solvent bath dissolves oils and provides a washing action to clean the parts.

Conveyorized Degreasing

Conveyorized degreasers operate either as cold or vapor degreasers. Because of their large work capacity, conveyorized degreasers actually emit less solvent per part cleaned than either open top vapor degreasers or cold cleaners. In conveyorized systems, most of the manual parts handling has been eliminated. Conveyorized degreasers are usually hooded or covered. The enclosure diminishes solvent losses from the system resulting from air movement within the plant. Conveyorized degreasers are used by a broad spectrum of metal working industries but are most often found in plants where there is enough production to provide a constant stream of products to be degreased.

4.2.2.2   Current Emission Estimation Methods

California Air Resources Board (CARB) Emission Estimates

California VOC emissions from degreasing are about equally divided between point and area sources. As reported in Section 4.1.2, our EDS verification survey uncovered some problems with classification of conveyorized degreasers as open-top vapor degreasers. Also, some cold cleaning emissions were found to be missing from the EDS. Our survey was not extensive enough, however, to permit us to generalize about point sources of degreasing emissions. The following is a discussion of the method used by the ARB to estimate area source degreasing emissions.

The EDS classifies degreasing emissions into four different area source categories:

- Manufacturing and Industrial - non-synthetic evaporation;
- Manufacturing and Industrial - synthetic evaporation;
- Manufacturing and Industrial (Maintenance Industries) - solvent evaporation; and
- Service and Commerce - non-synthetic evaporation

To determine 1979 county-by-county emission estimates for degreasers used in the manufacturing and maintenance industries, the CARB used 1976 data generated from a Eureka Laboratory, Inc. study (Leung et al., 1978). This study estimated total hydrocarbon emissions resulting from degreasing opera-

tions in California. Emissions of total organic gas (TOG) from the maintenance and manufacturing industries in 1976 were 7.78 and 85.2 tons per day, respectively. The 1976 estimates for manufacturing industry emissions were updated to 1979 by multiplying emissions by a 3.3-percent annual industry growth factor. (ARB staff were unable to provide SAI with a basis for this rate.) Growth of the maintenance industry was assumed to be zero and therefore 1976 emissions were unchanged in the 1979 emissions inventory. Growth factors were derived by reviewing studies performed by the Departments of Commerce and Agriculture, Bureau of Economics Analysis and Economic Research Services. Large point sources (those that emit greater than 25 tons per year according to the CARB Emission Data System) located in the county were subtracted from the final estimate. The annual county emission estimates were based on 365 days of activity during daylight working hours (Wong, 1982a).

Several items should be noted before judging the validity of these emission estimates. The data base from which the CARB calculated county-by-county emissions assumes that all degreasers in the manufacturing and maintenance industries are accounted for. The only way to verify this would, of course, be to survey all industries that use degreasers in California. The growth rate for maintenance industry-owned degreasers was not assumed to be equal to that of the manufacturing industry. The ARB uses a temporal activity period of 365 days per year. Using this parameter may lead to overestimates of emissions if activity occurs five or six days per week instead of seven. These industry growth rates may not be indicative of proportionate increases in degreasing TOG emissions. Finally, as is the case with all area source data, the degree of uncertainty associated with total organic gas emission calculations is not stated.

TOG emissions from degreasing operations at automobile repair shops are contained in the EDS area source category of "Service and Commerce - nonsynthetic evaporation." Emissions from these operations are small on an individual shop basis; however, because of the large number of such facilities, combined emissions from all repair shops are significant. Solvents used in these operations were assumed to be mineral spirits and Stoddard solvent. CARB procedures for determining TOG emissions from degreasing operations at automobile repair shops were developed from a report by Eureka Laboratories,

Inc. (Leung et al., 1978). Cold solvent degreasing devices used in the automotive repair industry are divided into two systems. One system uses parts washers serviced by Safety-Kleen Company and the other uses parts washers serviced by the individual repair shop owners. TOG emission rates from a typical degreaser in both systems have been calculated and used in CARB's area source methodology (Wong, 1982b). Emission estimates in the 1979 emissions inventory are based on the amount of emissions per washer (unit) per day and the number of the units per shop. Estimates of emissions per day per shop were then made.

Average emission factors of 1.20 and 1.89 pounds per day per shop for California facilities using Safety Kleen and non-Safety Kleen parts washers, respectively were calculated. County-wide emissions were calculated by multiplying an average emission factor of 1.63 pounds per day per shop by the number of licensed repair shops in the county.

The amount of degreasing solvent estimated by the Eureka Lab method may not reflect actual solvent usage in a county, since the data are not based on an actual survey of automotive repair facilities. The best way to determine solvent usage would be to survey all automotive repair shops in each county, or perhaps a stratified sample thereof. Synthetic solvent usage was not included in the 1979 inventory because its use was thought to be insignificant (Leung et al., 1978). Several assumptions have been made in order to make this methodology useful. Assumptions such as the emissions per day per unit can be highly variable depending on the type of work practices that are used. Also, the average number of units per shop (1.3) was based on those shops that use Safety-Kleen washers. This figure may not apply to shops that do not use this brand. Measures of uncertainty in TOG emission calculations in the 1979 emissions inventory are not stated. Since the uncertainty associated with the data is not known, the validity of the final emission estimates can not be interpreted.

Time and resource limitations did not permit us to include automotive repair facilities in our direct solvent consumption survey. With the aforementioned caveats, we believe that the CARB's area source methodology appears to be adequate for determining area source emissions from this category.

4.2.3   Cutback Asphalt and Road Oil

Asphalt is naturally present in most crude petroleum, from which it can be separated by various refinery processes. After a series of fractionations, the crude petroleum yields "petroleum asphalt," a solid or semi-solid cementitious material consisting mainly of bitumens. The two main types of petroleum asphalt used in road paving operations are asphalt cement and liquid asphalt (Wellborn and Griffith, 1960).

4.2.3.1   Source Description

Asphalts used for paving are usually prepared by heating the asphaltic material to a fluid state and mixing it with preheated aggregate material such as sand or gravel. The mixture must be applied to the road surface while it is still hot. As the asphalt cools, it begins to set. This procedure results in the release of only minimal amounts of volatile organic compounds into the atmosphere and these emissions are not included in the inventory for VOC emissions from asphalt paving sources. However, "hot mixes" cannot be used in all paving operations because of the need for a nearby "hot-mix" plant. When the use of hot-mix asphalt is not practical, liquid asphalts, which use petroleum diluents to facilitate handling and application of the asphalt cement, are used as "cold mixes."

Liquified asphalts can be classified as cutback asphalt, road oil and emulsified asphalt. Cutbacks are prepared by blending asphalt cement with various petroleum distillates such as naphtha, kerosene, No. 2 fuel oil, diesel oil or other volatile solvent. Road oils are either residual materials produced from the fractional distillation of certain crude petroleums, or a blend of asphalt cement with an oily petroleum fraction. Emulsified asphalts consist of minute globules of asphalt suspended in water treated with anionic or cationic surfactants.

Cutbacks and road oils are of three standard types: rapid curing (RC), medium curing (MC), and slow curing (SC). These types refer to the "setting time" or the time it takes for the solvent diluent fraction to evaporate, leaving the asphalt surface with the desired hardness or viscosity. Only

the MC and SC systems are currently used in California (Kemp, 1982). Cutbacks are included in the MC systems while road oils are grouped in the SC systems. Each of these systems can be subdivided into four grades with a numerical designation describing the minimum viscosity in centistokes (at 140°F) of each grade. The four grades are 70, 250, 800 and 3000.

Cutback Asphalt and Road Oil Use

Cutback asphalt and road oils are used for patching mixes, pavement sealants, dust palliatives, tack coats and as bonding agents between layers of paving material. Cutbacks can either be sprayed directly onto the road surface or mixed with aggregate material such as sand, rock or soil to provide a base for new pavement surfaces. Discussions with California Department of Transportation (Caltrans) officials revealed that the major users of cutback asphalt in California are the county road departments, followed by city and state road departments (Kemp, 1982). On a regional scale, road departments in the Central Valley and other California agricultural areas are high users of liquid asphalt mainly because hot-mix plants are not readily accessible (Pantalone and Humenny, 1979).

Table 4.2-7 shows asphalt sales by type of asphalt product in California for 1980. National domestic sales of all asphalts decreased by about 15 percent between 1979 and 1980. Sales of cutbacks and road oil in California decreased by 18 percent during the same period (Bodzer, 1981; Pearring, 1981). In 1980, cutback and road oil sales represented 6.8 percent of the total California sales of all asphalt paving products.

Emission Sources and Controls

Volatile organic compounds evaporate as the cutback asphalt cures. VOC emissions result from evaporation at both the job site and at the mixing plant. At the job site, hydrocarbons are emitted from application equipment and from direct spraying of cutback asphalt on the road surface. At the mixing plant, VOCs are released during mixing and stockpiling. The largest source of emissions, however, is the road surface itself (Markwordt and Bunyard, 1977).

Table 4.2-7

SALES OF ASPHALT IN CALIFORNIA, 1980

	Tons (10^6)	Percent Use
Asphalt cements	2.85	88.5
Emulsified	0.15	4.7
Cutback	0.11	3.4
Subtotal	3.11	
Road Oil	0.11	3.4
Total Sales of Asphalt, Asphalt Products and Road Oil	3.22	100.0

Source: Bodzer, 1981.

The VOC content in cutbacks ranges from 20 to 50 percent by volume, averaging 35 percent. The two major variables affecting both the quantity of VOC emitted and the time over which emissions occur are the type and the quantity of petroleum distillate used as diluent. Figure 4.2-2 gives an approximation of long term emissions from the use of RC, MC and SC cutback asphalts.

The use of cutback asphalt and road oils is assumed to occur mainly in rural portions of the state (Ipps, 1982). Cutback asphalt emissions in California tend to be concentrated in the agricultural areas of the Central Valley and the mountainous areas in northern California. Cutbacks are predominantly used during the summer months (May through October) when oxidant levels are at their annual peaks. According to the 1979 San Joaquin Valley emissions inventory, emissions from the use of liquid asphalt in road construction accounted for about 5.4 percent of total hydrocarbon emissions from stationary sources (Pinkerton et al., 1980). By contrast, the percent contribution of asphalt paving operation emissions to total stationary source hydrocarbon emissions in the South Coast and Bay Area Air Quality Management Districts, is 2.0 and 0.4 percent, respectively.

The substitution of emulsified asphalt (and road oils) for cutback is the major method of VOC emission control for road paving and maintenance operations (Kirwan and Maday, 1978). As mentioned earlier, emulsified asphalt is composed of asphalt cement mixed with a solution of 98 percent water and two percent of a non-volatile organic emulsifier (usually some type of caustic soap, clay or other such agent). Two types of emulsions are produced; anionic, and cationic. Emulsified asphalt can be substituted for cutbacks in all applications with the possible exception of when long-term stockpiles are required and when ambient temperature falls far below 50°F.

The ARB has estimated that by switching to emulsified asphalt, an energy savings equivalent to 8.4 million gallons of gasoline could be gained. The ARB also estimates that substituting emulsified asphalt or road oils for medium curing asphalt could result in an emission reduction of 56 and 50 tons per day, respectively, in California (Pantalone and Humenny, 1979).
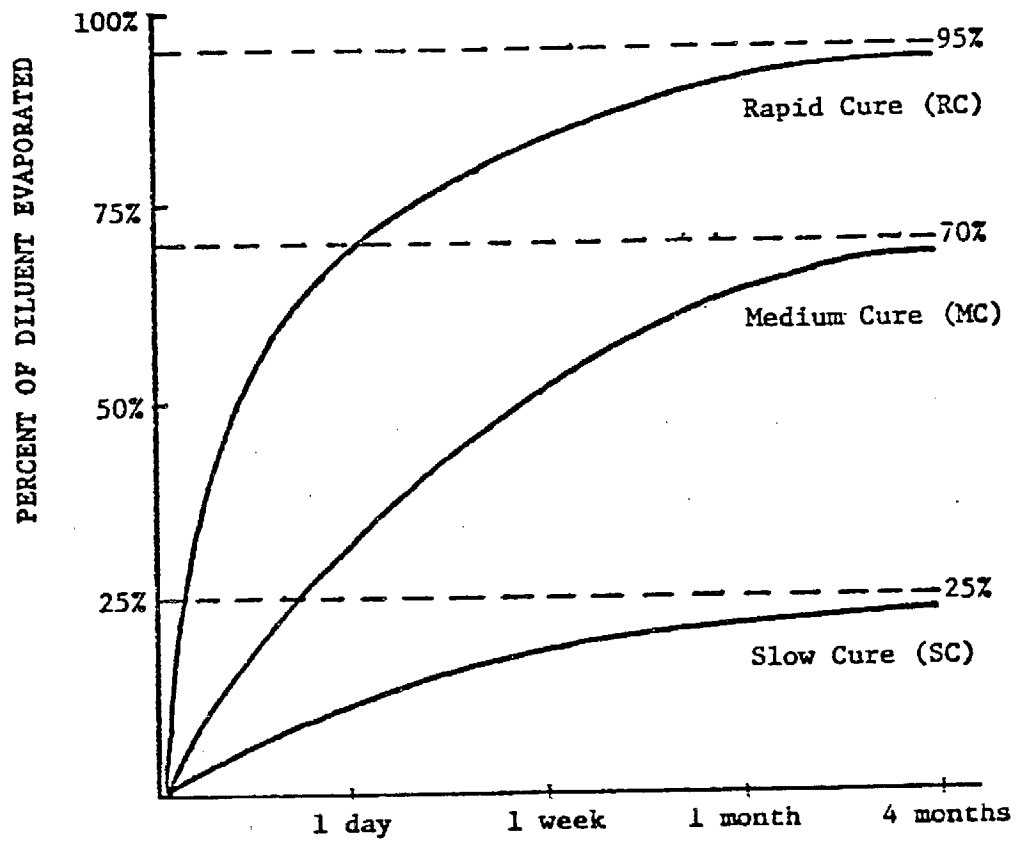
Source: Lahre (1980)

Figure 4.2-2. Percent of Diluent Evaporated from Cutback
Asphalt as a Function of Time

4.2.3.2 Current Emission Estimation Methods

The estimation of emissions from cutback asphalt on a regional and statewide level is complicated by the fact that several environmental parameters, including solar radiation, cloud cover, and air mass stagnation, may affect emission rates. Cutback asphalt and road oils come in a wide range of types and grades, each having different species and percent solvent content, further hindering accurate emissions estimation. The species that evaporate from cutback and road oil are considered to be moderately to highly photochemically reactive (Kirwan and Maday, 1978).

With these caveats in mind, the following discussion will focus on methodologies used by certain air pollution control districts (APCDs) to estimate cutback asphalt emissions. Since the vast majority of emissions evolve from road surfaces, cutback asphalt emissions are considered an area source. Discussions with local APCDs revealed two basic emission estimation methodologies. In some cases, all county, city and state road agencies in the APCD provide their estimates of total use of each type of asphalt. Emission estimates are made by using either emission factors derived from AP-42 data or from formulated emission factors based on physical properties of the cutback sold in the geographical region. The other emission estimation method relies on statewide totals of the sales of cutback and road oil from "Energy Data Reports" (Bodzer, 1981) which are scaled to county totals by applying either county to California population ratios or county to state ratios of road mileage. Emission factors are derived similarly as discussed above.

South Coast Air Quality Management District (SCAQMD)

According to 1979 SCAQMD emissions inventory, total reactive organic gas (ROG) emissions from "asphalt paving" equalled 13.8 tons/day (SCAQMD/SCAG, 1981). The SCAQMD calculates asphalt emissions on the basis of population. The District projected California liquid asphalt sales derived from the 1978 Energy Data Reports - Sales of Asphalt [California] to 1979. South Coast Air Basin to California population ratios are used to scale total California asphalt sales to local levels. Emission factors for cutback and road oils are obtained from data in the documentation of the ARB 1977 area source emission

inventory. These emission factors are based primarily on physical properties of each type of asphalt, as illustrated in Figure 4.2-2, and asphalt industry specifications. Temporal data were applied, using the assumption that cutback use occurs mainly during summer months (Grisinger, 1981b).

Two basic problems are evident with this methodology. First, the assumption that asphalt use can be apportioned by population seems tenuous. As discussed above, cutbacks and road oils are used in large quantities in rural areas, thereby rendering population factors invalid. If such a factor must be applied to total California asphalt sales, it seems that the use of a factor based on road mileage would be more accurate. Second, the temporal nature of asphalt paving in the South Coast Air Basin may not be restricted to just summer months. Because Southern California experiences dryer and warmer winters compared to other parts of the state, cutback use may occur, albeit to a lesser extent, during winter months. The use of a summer month temporal variation may therefore lead to overestimates of emissions.

Bay Area Air Quality Management District (BAAQMD)

Hydrocarbon emissions from "asphalt paving" in the BAAQMD equalled 3.3 tons/day in 1979 (BAAQMD, 1981). For 1979, the District calculated these emissions on the basis of road mileage. The ratio of road mileage in the BAAQMD to road mileage in the state was used to scale California asphalt sales from the 1979 Energy Data Reports to regional district totals. Data on road mileage were obtained from California Statistical Abstracts. The BAAQMD uses emission factors reported in the ARB proposed model rule for asphalt use (Pantalone and Humenny, 1979). Emission factors were derived by using predicted percent solvent evaporation from each type of cutback and road oil (see Figure 4.2-2) and the percent petroleum distillate in each asphalt. A temporal period of 365 days/year was used to calculate daily hydrocarbon emissions in the BAAQMD (Flynn, 1982).

The validity of the assumption that asphalt use can be apportioned by road mileage is examined in Section 4.2.3.3. This methodology cannot provide as accurate a picture of asphalt use as a survey of end users and/or manufacturers of asphalt would give. The use of a temporal period of 365 days

Table 4.2-8

EVAPORATIVE VOC EMISSIONS FROM CUTBACK ASPHALT AS A FUNCTION
OF DILUENT CONTENT AND CUTBACK ASPHALT TYPE[a]

Type of Cutback[b]	Percent, By Volume, of Diluent in Cutback[c]		
	25	35	45
Rapid cure	17	24	32
Medium Cure	14	20	26
Slow Cure	5	8	10

Source: Lahre, 1980.

[a] These numbers represent the percent, by weight, of cutback asphalt evaporated.

[b] Typical densities assumed for diluents used in RC, MC and SC cutbacks are 0.7, 0.8 and 0.9 Kg/L, respectively.

[c] Diluent content typically range between 25 to 45 percent, by volume.

If physical properties of cutback used locally are known, the following equations can be solved for the volume of diluent (x) and volume of asphalt cement (y):

(total amount of cutback used) = (x, volume of diluent) (density of diluent)
+ (y, volume of asphalt cement) (density of asphalt cement),

and x = percent, by volume, diluent
    y = percent, by volume, asphalt cement

Using data from Figure 4.2-2, the percent, by weight, of solvent evaporated can be derived.

per year may also lead to inaccuracies in daily emissions. To enable better estimation of emission factors, local road agencies should provide data on temporal variations in cutbacks application and the physical properties of the asphalt being used.

Fresno County Air Pollution Control District (FCAPCD)

In 1979, total hydrocarbon emissions from asphalt use in road construction in the San Joaquin Valley equalled 17.65 tons/day. For the 1979 San Joaquin Valley emissions inventory the FCAPCD surveyed all city and county road departments for their use of asphalt. Local Caltrans asphalt usage was also apportioned to each county. Temporal data were based on the assumption that cutback use occurs mainly during the summer months (165 days/year). Emission factors were formulated for each cutback system (MC,SC) and grade by multiplying the percent diluent (by weight) of the cutback by the percentage of diluent that evaporates. Percent diluent data were derived from an ARB survey of asphalt and road oil vendors (Pantalone and Humenny, 1979). Each county's throughput was multiplied by the appropriate emission factor to estimate total hydrocarbon emissions (Pinkerton et al., 1980).

Smaller APCDs in the state have the ability to contact all road agencies in their district to obtain asphalt use information. Shasta County compiles the total use of asphalt and then applies emission factors from AP-42 (Lahre, 1980) to calculate emissions (Anon., 1982). Table 4.2-8 is an example of information given in AP-42.

California Air Resources Board (ARB)

For the 1979 emissions inventory, the ARB used total California sales of asphalt as compiled by the U.S. Department of Energy's (USDOE) Energy Data Reports and derived county use by applying the ratio of county to state asphalt-paved mileage (Ipps, 1982). County emissions of VOC from cutback asphalt and road oils are computed by applying emission factors (whose derivation are described above) to county asphalt use.

The Energy Data Reports-Sales of Asphalt was compiled by surveying every manufacturer of asphalt in the U.S.   After discussions with a representative from the Department of Energy, it was discovered that the initial published figures for California sales of asphalt in 1979 were in error (Bodzer, 1982).   Revised figures for sales of asphalt in 1979 were published in Bodzer (1981).   For the 1979 emissions inventory, the CARB used the erroneous figures published in 1980 (USDOE, 1980).   Comparisons between 1979 California asphalt use data used by the ARB and the revised figures are shown below:

<div align="center">

DOE Published Asphalt
Use for California

</div>

	Initial	Revised
	(tons/year)	
Cutback Asphalt	134,699	155,947
Road Oil	86,742	111,790

Tables 4.2-9 and 4.2-10 show comparisons of cutback asphalt and road oil use and associated TOG emissions by California air basin and county using data from the 1979 emissions inventory (Ipps, 1982) and SAI's estimates using the revised DOE data. Tables 4.2-11 and 4.2-12 show the same comparisons for the South Coast and Bay Area Air Quality Management Districts.   Incorporation of the revised figures reflects a 16 and 29 percent increase in use and emissions for cutback asphalt and road oil, respectively, in California.

Discussions with a representative of the Asphalt Institute revealed that Energy Data Report figures may not be indicative of actual consumption (Pearring, 1982); the assumption that sales are indicative of consumption must be made.   The USDOE no longer publishes Energy Data Reports.   The Asphalt Institute now conducts its own yearly "member" survey of asphalt manufacturers, but state data are incomplete since only a few California refineries are members.

4.2.3.3   SAI Survey of California Asphalt Use, 1980

The main objectives of this survey were (1) to examine the validity of the assumption that total state asphalt use can be apportioned to counties

Table 4.2-9

REVISED ESTIMATES OF CUTBACK ASPHALT USE AND EMISSIONS
FOR THE 1979 EMISSIONS INVENTORY, BY CALIFORNIA AIR BASIN AND COUNTY

Air Basin	County	Cutback Used[a] (tons/year)		TOG Emissions (tons/year)	
		ARB Totals[b]	Revised Totals[c]	ARB Totals[b]	Revised Totals
GBV	Alpine	143	166	17.85	20.75
	Inyo	1,432	1,657	178.98	207.13
	Mono	629	728	78.63	91.00
LC	Lake	779	901	97.32	112.63
LT	El Dorado	446	516	55.73	64.50
	Placer	88	101	10.94	12.63
MC	Amador	505	584	63.14	73.00
	Calaveras	761	881	95.13	110.13
	El Dorado	823	953	102.88	119.13
	Mariposa	709	820	88.56	102.50
	Nevada	819	948	102.37	118.50
	Placer	890	1,031	111.30	128.88
	Plumas	851	986	106.41	123.25
	Sierra	366	423	45.80	52.88
	Tuolumne	780	904	97.49	113.00
NC	Del Norte	404	467	50.51	58.38
	Humboldt	1,751	2,028	218.89	253.50
	Mendocino	1,354	1,566	169.22	195.75
	Sonoma	280	325	35.02	40.63
	Trinity	826	956	103.21	119.50
NCC	Monterey	1,708	1,977	213.50	247.13
	San Benito	582	673	72.74	84.13
	Santa Cruz	893	1,033	111.63	129.13
NEP	Lassen	1,297	1,502	162.14	187.75
	Modoc	1,173	1,358	146.65	169.75
	Shasta	135	155	16.84	19.38
	Siskiyou	2,752	3,186	343.99	398.25
SC	Los Angeles	20,260	23,457	2,532.51	2,932.13
	Orange	5,430	6,287	678.71	785.88
	Riverside	4,065	4,707	508.15	588.38
	San Bernardino	6,452	7,470	806.51	933.75
SCC	Santa Barbara	1,763	2,042	220.40	255.25
	San Luis Obispo	1,860	2,153	232.52	269.13
	Ventura	2,381	2,758	297.68	344.75
SD	San Diego	6,950	8,047	868.81	1,005.88
SED	Imperial	2,425	2,806	303.07	350.75
	Kern	842	974	105.23	121.75
	Los Angeles	226	263	28.29	32.88
	Riverside	1,662	1,925	207.78	240.63
	San Bernardino	1,351	1,565	168.88	195.63
SF	Alameda	3,141	3636	392.65	454.50
	Contra Costa	2,806	3,248	350.72	406.00
	Marin	1,183	1,369	147.83	171.13

Table 4.2-9

REVISED ESTIMATES OF CUTBACK ASPHALT USE AND EMISSIONS
FOR THE 1979 EMISSIONS INVENTORY, BY CALIFORNIA AIR BASIN AND COUNTY
(Continued)

Air Basin	County	Cutback Used[a] (tons/year) ARB Totals[b]	Revised Totals[c]	TOG Emissions (tons/year) ARB Totals[b]	Revised Totals
	Napa	808	936	101.02	117.00
	Santa Clara	4,401	5,095	550.08	636.88
	San Francisco	964	1,036	120.56	129.50
	San Mateo	1,996	2,312	249.53	289.00
	Solano	1,110	1,265	138.74	158.13
	Sonoma	2,072	2,398	258.96	299.75
SJV	Fresno	4,958	5,741	619.78	717.63
	Kern	4,418	5,115	552.27	639.38
	Kings	985	1,140	123.08	142.50
	Madera	1,928	2,232	240.94	279.00
	Merced	2,066	2,392	258.29	299.00
	San Joaquin	2,775	3,213	346.85	401.63
	Stanislaus	2,589	2,998	323.61	374.75
	Tulare	4,530	5,244	566.24	655.50
SV	Butte	1,705	1,974	213.16	246.75
	Colusa	734	850	91.76	106.25
	Glenn	1,001	1,159	125.10	144.88
	Sacramento	3,533	4,090	441.64	511.25
	Shasta	1,940	2,246	242.46	280.75
	Solano	356	412	44.45	51.50
	Sutter	947	1,096	118.37	137.00
	Tehama	955	1,106	119.38	138.25
	Yolo	1,313	1,520	164.16	190.00
	Yuba	645	747	80.65	93.38
	Total	134,702	155,849	16,837.69	19,481.27

[a] USDOE state asphalt use totals were apportioned to counties by applying ratio of county to state ratios of mileage of asphalt-paved roads; amounts shown reflect only the liquid portions of the paving mix and do not include the aggregate reinforcement.

[b] Ipps, 1982.

[c] 1979 California asphalt sales from Bodzer, 1981.

Table 4.2-10

REVISED ESTIMATES OF ROAD OIL USE AND EMISSIONS FOR THE 1979
EMISSIONS INVENTORY BY; CALIFORNIA AIR BASIN AND COUNTY

Air Basin	County	Road Oil Used[a] (tons/year) ARB[b]	Revised[c]	TOG Emissions (tons/year) ARB[b]	Revised
GBV	Alpine	92	119	2.67	3.45
	Inyo	922	1,188	26.74	34.45
	Mono	405	522	11.75	15.14
LC	Lake	501	646	14.54	18.73
LT	El Dorado	287	370	8.33	10.73
	Placer	56	72	1.64	2.09
MC	Amador	325	419	9.43	12.15
	Colusa	490	609	14.21	17.66
	El Dorado	530	683	15.37	19.81
	Mariposa	456	588	13.23	17.05
	Nevada	527	679	15.29	19.69
	Placer	573	739	16.63	21.43
	Plumas	548	707	15.90	20.50
	Sierra	236	304	6.84	8.82
	Tuolumne	502	648	14.56	18.79
NC	Del Norte	260	334	7.55	9.69
	Humboldt	1,128	1,453	32.70	42.14
	Mendocino	872	1,123	25.28	32.57
	Sonoma	180	233	5.23	6.76
	Trinity	532	686	15.42	19.89
NCC	Monterey	1,100	1,417	31.90	41.09
	San Benito	375	482	10.87	13.98
	Santa Cruz	575	741	16.68	21.49
NEP	Lassen	835	1,076	24.22	31.20
	Modoc	756	974	21.91	28.25
	Shasta	87	111	2.52	3.22
	Siskiyou	1,772	2,284	51.39	66.24
SC	Los Angeles	13,047	16,815	378.36	487.64
	Orange	3,497	4,507	101.40	130.70
	Riverside	2,618	3,374	75.92	97.85
	San Bernardino	4,155	5,355	120.49	155.30
SCC	Santa Barbara	1,135	1,463	32.93	42.43
	San Luis Obispo	1,198	1,544	34.74	44.78
	Ventura	1,534	1,977	44.47	57.33
SD	San Diego	4,476	5,768	129.80	167.27
SED	Imperial	1,561	2,012	45.28	58.35
	Kern	542	698	15.72	20.24
	Los Angeles	146	188	4.23	5.45
	Riverside	1,070	1,380	31.04	40.02
	San Bernardino	870	1,122	25.23	32.54
SF	Alameda	2,023	2,607	58.66	75.60
	Contra Costa	1,807	2,328	52.40	67.51
	Marin	762	981	22.09	28.45

Table 4.2-10

REVISED ESTIMATES OF ROAD OIL USE AND EMISSIONS FOR THE 1979 EMISSIONS INVENTORY BY; CALIFORNIA AIR BASIN AND COUNTY
(Continued)

Air Basin	County	Road Oil Used[a] (tons/year) ARB[b]	Road Oil Used[a] (tons/year) Revised[c]	TOG Emissions (tons/year) ARB[b]	TOG Emissions (tons/year) Revised
	Napa	520	671	15.09	19.46
	Santa Clara	2,834	3,652	82.18	105.91
	San Francisco	621	801	18.01	23.23
	San Mateo	1,286	1,657	37.28	48.05
	Solano	715	921	20.73	26.71
	Sonoma	1,334	1,719	38.69	49.85
SJV	Fresno	3,193	4,115	92.60	119.34
	Kern	2,845	3,667	82.51	106.34
	Kings	634	817	18.39	23.69
	Madera	1,241	1,600	36.00	46.40
	Merced	1,331	1,715	38.59	49.74
	San Joaquin	1,787	2,303	51.82	66.79
	Stanislaus	1,667	2,149	48.35	62.32
	Tulare	2,917	3,759	84.60	109.01
SV	Butte	1,098	1,415	31.85	41.04
	Colusa	473	609	13.71	17.66
	Glenn	644	831	18.69	24.10
	Sacramento	2,275	2,932	65.98	85.03
	Shasta	1,249	1,610	36.22	46.69
	Solano	229	295	6.64	8.56
	Sutter	610	785	17.68	22.77
	Tehama	615	793	17.84	23.00
	Yolo	846	1,090	24.53	31.61
	Yuba	415	536	12.05	15.54
	Total	86,742	111,768	2,515.59	3,241.31

[a] USDOE state asphalt use totals were apportioned to counties by applying ratios of mileage of asphalt paved-roads; amounts shown reflect only the liquid portions of the paving mix and do not include the aggregate reinforcement.

[b] Ipps, 1982

[c] 1979 California asphalt sales from Bodzer, 1981.

Table 4.2-11

REVISED ESTIMATES OF ASPHALT USE AND EMISSIONS FROM CUTBACK
ASPHALT AND ROAD OIL FOR THE 1979 EMISSIONS INVENTORY - SOUTH COAST
AIR BASIN SUMMARY

Asphalt Type	Total Asphalt Used (tons/year)		TOG Emissions (tons/year)	
	ARB[a]	Revised[b]	ARB[a]	Revised
Cutback	36,207	41,921	4,525.88	5,240.14
Road Oil	23,317	30,051	676.17	871.49
Total	59,524	71,972	5,202.05	6,111.63

[a] Ipps, 1982

[b] 1979 California asphalt sales from Bodzer, (1981).

Table 4.2-12

REVISED ESTIMATES OF ASPHALT USE AND EMISSIONS FROM CUTBACK ASPHALT
AND ROAD OIL FOR THE 1979 EMISSION INVENTORY - SAN FRANCISCO
BAY AREA SUMMARY

Asphalt Type	Total Asphalt Used (tons/year)		TOG Emissions (tons/year)	
	ARB[a]	Revised[b]	ARB[a]	Revised
Cutback	18,481	21,295	2,310.09	2,661.89
Road Oil	11,902	15,337	345.13	444.77
Total	30,383	36,632	2,655.22	3,106.66

[a] Ipps, 1982

[b] 1979 California asphalt sales from Bodzer, (1981).

by applying ratios of county-to-state mileage of asphalt-paved roads, and (2) to obtain an indication of the magnitude of asphalt use in various counties and regions in the state. Time and budget contraints prevented a thorough statewide survey of total California asphalt use. A survey of all county, city, and state road departments, road maintenance contractors, utility companies and refineries would be the ideal method to obtain an accurate picture of statewide asphalt use.

Methods

For the SAI survey, all 58 California county, 11 Caltrans district, and 39 selected city road departments were contacted. Road departments representing the 20 largest cities in the South Coast Air Basin and the 19 largest cities in the Bay Area, based on population, were selected. Each road department was sent a letter inquiring about the amounts of the four different grades of cutback asphalt (MC) and road oil (SC) used in its calendar year 1980 road maintenance and construction projects. Figure 4.2-3 is a copy of the letter sent to all road departments. Caltrans districts were asked to specify use by each county in their jurisdiction. If this was not possible, a list of counties within the jurisdiction of the district was obtained. Total district use was then scaled to county use by applying road mileage ratios. Road departments were also asked to provide the amount of MC and SC liquid asphalt used by their outside contractors. Since cutback and road oils are often combined with aggregate of sand, rock or gravel in a "mix," road departments were asked to provide only the amount of the liquid oil fraction. The fraction ranged from five to six percent, by weight.

If, after 30 days, a response was not received, follow-up phone calls were initiated. In some cases, city and county road departments claimed that their outside contractors were the only ones who could provide the necessary information. If this was the case, letters were sent to the contractors inquiring about the amounts of MC and SC used in county- and/or city-sponsored road projects.

<Date>

Contact Name
Name of Road Department
Address

Dear   :

Science Applications, Inc. (SAI) would like your help in a research project we are conducting for the California Air Resources Board (CARB) (Contract No. AO-101-32). The CARB and local air pollution control districts maintain emission inventories which keep track of various types of air pollutant emissions from thousands of stationary sources in California. Because these emission data bases are used for new source reviews and in predicting air quality trends, it is essential that they be up-to-date and accurate.

One task in our study is to determine VOC emissions from cutback liquid asphalt use in all California counties and air basins. We are in the process of obtaining cutback asphalt use data from every California county and CALTRANS district. It would be of great assistance to our research if you could tell us how many pounds of the following cutback asphalt and road oil types were used in your <Name of Road Dept.> road project contracts during Calendar Year 1980:

Medium Cure Systems	Slow Cure Systems
70	70
250	250
800	800
3000	3000

Please give only the amount of liquid, not the total amount of liquid plus aggregate used. We are interested in the amounts used directly by your department and by outside contractors working on <Name of Road Dept.>-sponsored projects. If you are unable to break down cutback asphalt use according to the above asphalt grade designation system, please supply any and all information (including physical properties of the asphalt binder, if available) that will enable us to derive the total use for your city.

Science Applications, Inc. 1900 Avenue of the Stars Suite 900 Los Angeles California 90067

We would appreciate a response as soon as possible. If you have any questions please call Mr. Richard Rapoport or myself at (213) 553-2705. The CARB research contract monitor is Mr. Joseph Pantalone, who may be reached at (916) 323-1535.

Thank you very much for your cooperation.

Sincerely,

SCIENCE APPLICATIONS, INC.

Michael B. Rogozen, D.Env.
Principal Investigator
CARB Emission Inventory Project

Figure 4.2-3.   Letter Sent to Road Departments for SAI Cutback Asphalt and Road Oil Survey.

Results

Table 4.2-13 shows the response status for the cutback asphalt/road oil survey. The response rates for all three road department categories are greater than 90 percent. One Caltrans district, consisting mainly of northwestern counties, did not provide information. The two counties which did not respond asked that their surveys be forwarded to local contractors who, in turn, did not respond. The same situation was encountered for the non-responding city road departments.

Tables 4.2-14 and 4.2-15 present the amounts of cutback asphalt and road oil, respectively, reported by all surveyed road department categories in California in 1980. Ten out of 56 county and 16 out of 36 city road departments reported no use of either MC or SC liquid asphalt in 1980. Fresno, Santa Barbara and San Luis Obispo Counties reported the highest total cutback use of all surveyed counties, totalling 4.07, 4.32 and 5.09 million pounds, respectively. Total California cutback use in 1980, according to the SAI survey, equalled 48.15 million pounds. San Diego, San Bernardino and Riverside Counties reported the highest total road oil use of all surveyed counties, totalling 16.47, 13.04 and 5.56 million pounds, respectively. Total California road oil use, according to the SAI survey, equalled 63.49 million pounds. The data described above do **not** reflect actual total cutback and road oil use in California, as many city road departments were not contacted. It was discovered later that utility companies such as water and power departments are also potential users of cutback asphalt, and that other departments besides road departments within a public works agency may also use cutback asphalt in certain operations.

Since all road departments reported asphalt use by type (MC or SC) and by grade (70, 250, 800 or 300), emission factors specific to each type and grade of asphalt were applied to calculate total organic gas (TOG) emissions. Emission factors in Table 4.2-16 are based on the percent of petroleum distillates in each asphalt type and the percent solvent evaporated therefrom (Tollstrup, 1982b; Lahre, 1980). The former is based on data from local refineries producing cutback and road oils and the latter from experimental data (Markwordt and Bunyard, 1977). Table 4.2-17 presents the results of our

Table 4.2-13

SAI CALIFORNIA CUTBACK ASPHALT AND ROAD
OIL USE SURVEY RESPONSE STATUS

Road Department Category	Response	No Response	Total Surveyed	Response Rate for Each Category (%)
Counties	56	2	58	97
Cities[a]	36	3	39	92
Caltrans Districts	10	1	11	91
Totals	102	6	108	94

[a] 20 cities in South Coast; 19 cities in Bay Area

Table 4.2-14

SAI SURVEY OF CUTBACK ASPHALT USE, 1980, BY CALIFORNIA COUNTY
(Use in 1,000,000 lb)

County	County Road Dept.	City Road Dept.	Caltrans	Total Use for County
Alameda	0	0.250	0.133	0.383
Alpine	0	-	0.060	0.060
Amador	0	-	0.180	0.180
Butte	0	-	0.187	0.187
Calaveras	0	-	0.012	0.012
Colusa	0	-	0.022	0.022
Contra Costa	0.030	0	0.071	0.101
Del Norte	0	-	ND	NA
El Dorado	0.150	-	0.095	0.245
Fresno	4.0	-	0.070	4.070
Glenn	0.750	-	0.062	0.812
Humboldt	0.750	-	ND	0.750[a]
Imperial	0.584	-	0.288	0.872
Inyo	0	-	1.500	1.500
Kern	0	-	0.120	0.120
Kings	0	-	0.021	0.021
Lake	0	-	ND	NA
Lassen	0.216	-	0.851	1.067
Los Angeles	0.617	0.761	0.172	1.550
Madera	1.470	-	ND	1.470[a]
Marin	0	-	0.062	0.062
Mariposa	0.761	-	0.184	0.945
Mendocino	2.848	-	ND	2.848[a]
Merced	0	-	0.072	0.072
Modoc	0.286	-	ND	0.286
Mono	0.390	-	0.500	0.890
Monterey	0.063	-	3.888	3.951
Napa	ND	-	0.071	0.071[a]
Nevada	0.006	-	0	0.006
Orange	0	ND	0.672	0.672[a]
Placer	0.409	-	ND	0.409[a]
Plumas	0.328	-	0.633	0.961
Riverside	0	0	0	0
Sacramento	ND	-	0.006	0.006[a]
San Benito	1.083	-	1.296	2.379
San Bernardino	0.930	0	0	0.930

Table 4.2-14 (Continued)

SAI SURVEY OF CUTBACK ASPHALT USE, 1980, BY CALIFORNIA COUNTY
(Use in 1,000,000 lb)

County	County Road Dept.	City Road Dept.	Caltrans	Total Use for County
San Diego	0	NA[b]	1.097	1.097
San Francisco	0.080		0.027	0.107
San Joaquin	0.589	-	0.024	0.613
San Luis Obispo	0.195	-	4.896	5.091
San Mateo	0	0.086	0.133	0.219
Santa Barbara	0	-	4.320	4.320
Santa Clara	0.055	0.084	0.160	0.299
Santa Cruz	0	-	0.080	0.080
Shasta	0.027	-	0.403	0.430
Sierra	0.020	-	0.062	0.082
Siskiyou	0.294	-	0.003	0.297
Solano	0.360	0.003	0.180	0.543
Sonoma	2.750	-	0.151	2.901
Stanislaus	0	-	ND	NA
Sutter	0.054	-	0	0.054
Tehama	1.245	-	0.230	1.475
Trinity	0.3116	-	0.311	0.627
Tulare	0	-	0.049	0.049
Tuolumne	ND	-	ND	NA
Ventura	0	-	1.618	1.618
Yolo	0.300	-	0.039	0.339
Yuba	0	-	0	0
Totals	21.956	1.184	25.011	48.151

ND - No data available

NA - Not able to make calculation

[a] Missing data

[b] County and City road departments are under same jurisdiction

Blanks signify that city road departments were not contacted.

Table 4.2-15

SAI SURVEY OF ROAD OIL USE, 1980, BY CALIFORNIA COUNTY
(Use in 1,000,000 lb)

County	County Road Dept.	City Road Dept.	Caltrans	Total Use for County
Alameda	0	0.006	0.035	0.041
Alpine	0	-	0	0
Amador	0	-	0	0
Butte	0.006	-	0.009	0.015
Calaveras	0.382	-	0.096	0.478
Colusa	0.370	-	0	0.370
Contra Costa	0.147	0.030	0.019	0.196
Del Norte	0	-	ND	NA
El Dorado	0	-	0	0
Fresno	4.000	-	0.670	4.670
Glenn	0	-	0.005	0.005
Humboldt	0	-	ND	NA
Imperial	1.499	-	0	1.499
Inyo	0.312	-	0	0.312
Kern	1.256	-	1.141	2.397
Kings	0.130	-	0.198	0.328
Lake	0	-	ND	NA
Lassen	0.904	-	0	0.904
Los Angeles	1.700	0.142	0.164	2.006
Madera	0.949	-	ND	0.949[a]
Marin	0	-	0.017	0.017
Mariposa	0.257	-	0.012	0.269
Mendocino	0.029	-	ND	0.029[a]
Merced	3.400	-	0.042	3.442
Modoc	0	-	ND	NA
Mono	0.024	-	0	0.024
Monterey	0	-	1.005	1.005
Napa	ND	-	0.091	0.091[a]
Nevada	0.247	-	0	0.247
Orange	0	ND	0	NA
Placer	0.180	-	ND	0.180[a]
Plumas	0.021	-	0	0.021
Riverside	4.164	0	1.400	5.564
Sacramento	ND	-	0	NA
San Benito	0	-	0.335	0.335
San Bernardino	10.467	0.619	1.950	13.036
San Diego	15.800	-[b]	0.674	16.474
San Francisco	0	NA[b]	0.007	0.007
San Joaquin	0.445	-	0.024	0.469
San Luis Obispo	0.195	-	1.266	1.461
San Mateo	0.154	0.001	0.035	0.190

Table 4.2-15 (Continued)

SAI SURVEY OF ROAD OIL USE, 1980, BY CALIFORNIA COUNTY
(Use in 1,000,000 lb)

County	County Road Dept.	City Road Dept.	Caltrans	Total Use for County
Santa Barbara	0.418	-	1.117	1.535
Santa Clara	0	0.02	0.042	0.062
Santa Cruz	0	-	0.021	0.021
Shasta	0	-	0	0
Sierra	0.020	-	0	0.02
Siskiyou	0	-	0	0
Solano	0.060	0	0	0.060
Sonoma	0	-	0.040	0.040
Stanislaus	0.432	-	ND	0.432[a]
Sutter	0.198	-	0.004	0.202
Tehama	0	-	0	0
Trinity	0	-	0	0
Tulare	1.560	-	0.471	0.031
Tuolumne	ND	-	ND	NA
Ventura	0	-	1.524	1.524
Yolo	0.360	-	0	0.360
Yuba	0.171	-	0.004	0.175
Totals	50.257	0.818	12.418	63.493

ND - no data available

NA - not able to make calculation

[a] Missing data

[b] County and City of San Francisco are under same jurisdiction

Blanks signify that city road departments were not contacted.

Table 4.2-16

EMISSION FACTORS USED TO CALCULATE TOTAL ORGANIC GAS (TOG) EMISSIONS
FROM CUTBACK ASPHALT AND ROAD OIL USE DATA COMPILED IN SAI SURVEY

Type of Asphalt	TOG Emission Factor (pounds of emission/ton of asphalt)
Cutback Asphalts:	
MC - 70	463
MC - 250	315
MC - 800	241
MC - 3000	132
Road Oils:	
SC - 70	160
SC - 250	118
SC - 800	69
SC - 3000	32

Source: Tollstrup, 1982b.

TOG emission calculations for all counties. San Diego, San Luis Obispo and Fresno Counties have the highest county TOG emission total of all other counties, equalling 371, 331 and 321 tons per year, respectively. Total TOG emissions from the state from SAI survey equals 4,299 tons per year.

Regression Analysis

As mentioned earlier, several APCDs and the ARB assume that statewide asphalt use totals can scaled to county use by applying county-to-state ratios of mileage of asphalt-paved roads. The purpose of the following discussion is to examine the validity of this assumption. Eight linear regression analyses were performed, four for all counties and four for all counties except the large urban counties of Los Angeles, Riverside, San Bernardino and San Diego. Table 4.2-18 presents 1980 mileage of asphalt-paved roads by county. Table 4.2-19 shows the results of the regression analyses for the eight data sets. Certain counties were omitted from the analyses if cutback or road oil use data were missing. Ninety-five-percent confidence intervals for the correlation coefficient (r) and probability values (p-values) were calculated using tables in Dixon and Massey (1969). All correlation coefficients for plots involving county road oil use and emissions versus mileage are statistically significant at the 95 percent confidence level but are quite low. None of the correlation coefficients for plots involving cutback asphalt use and emissions versus mileage is statistically significant at the 95 percent confidence level. This implies that there is no linear association between cutback use and emissions versus mileage at the 95 percent confidence level (i.e. the variation in cutback use or emissions by county is not explained well by a linear regression function plotted versus mileage).

The exclusion of large urban counties from the data set results in a slight increase in the correlation coefficient. For example, r for road oil use versus mileage (all counties) equals 0.48. This implies that asphalt mileage explains 23 percent of the variation in cutback use. When selected urban counties are excluded, this figure increases to 27 percent. The data compiled by SAI tend to support the assumption that road mileage may be used to apportion state road oil use totals to the counties, but that the assumption weakens when larger urban counties are included. Conversely, this assumption does not hold for apportionments of cutback asphalt use.

Table 4.2-17

TOTAL ORGANIC GAS EMISSIONS FROM CUTBACK
ASPHALT AND ROAD OIL, 1980, BY CALIFORNIA COUNTY
FROM SAI SURVEY
(Emissions in tons/year)

County	Cutback Asphalt Emissions	Road Oil Emissions	Total Emissions[a] for County
Alameda	30.51	1.11	31.62
Alpine	3.62	0	3.62
Amador	10.85	0	10.85
Butte	11.26	0.33	11.59
Calaveras	0.72	13.68	14.40
Colusa	1.33	6.38	7.71
Contra Costa	8.74	6.03	14.77
Del Norte	ND	ND	ND
El Dorado	17.53	0	17.53
Fresno	244.76	75.85	320.61
Glenn	62.82	0.09	62.91[b]
Humboldt	59.06	0	59.06[b]
Imperial	63.34	14.80	78.14
Inyo	90.38	5.38	95.76
Kern	4.70	41.63	46.33
Kings	0.82	4.27	5.09[b]
Lake	0	ND	0[b]
Lassen	67.80	16.82	84.62
Los Angeles	88.48	34.99	123.47
Madera	89.56	16.37	105.93
Marin	5.57	0.44	6.01
Mariposa	31.19	6.56	37.75[b]
Mendocino	200.58	0.87	201.45[b]
Merced	2.38	59.37	61.75
Modoc	17.23	0.	17.23
Mono	53.62	0.96	54.58
Monterey	241.50	17.25	258.75[b]
Napa	6.38	0.49	6.87[b]
Nevada	0.74	9.88	10.62[b]
Orange	52.92	0	52.92[b]
Placer	29.87	3.11	32.98[b]
Plumas	57.84	0.85	58.69[b]
Riverside	0	103.98	103.98[b]
Sacramento	0.35	0	0.35[b]
San Benito	161.11	5.78	166.89[b]
San Bernardino	107.64	210.60	318.24[b]
San Diego	81.06	289.94	371.00
San Francisco	11.65	0.19	11.84
San Joaquin	49.22	13.54	62.76
San Luis Obispo	306.73	25.19	331.92
San Mateo	13.98	3.61	17.59
Santa Barbara	260.28	29.34	289.62
Santa Clara	21.30	2.01	23.31
Santa Cruz	7.17	0.56	7.73
Shasta	26.00	0	26.00
Sierra	5.10	0.47	5.57
Siskiyou	15.88	0	15.88
Solano	32.89	1.04	33.93
Sonoma	179.23	1.06	180.29[b]
Stanislaus	0	10.16	10.16[b]
Sutter	6.10	3.95	10.05
Tehama	111.90	0	111.90
Trinity	55.29	0	55.29
Tulare	6.83	50.85	57.68
Tuolumne	0	0	0[b]
Ventura	113.64	29.16	142.80
Yolo	37.12	10.62	47.74
Yuba	0	3.01	3.01
Totals	3,166.57	1,132.57	4,299.14

ND - no data available; county did not respond.

[a] Data on individual counties are likely to be lower than actual total county use, as most of city road departments in the state were not surveyed.

[b] Data from either county, state or city road departments not received.

Table 4.2-18

STATE OF CALIFORNIA

1980 MILEAGE OF ASPHALT PAVED PUBLIC ROADS IN EACH COUNTY

County	Total Miles	County	Total Miles
Alameda	2,616	Orange	5,087
Alpine	129	Placer	636
Amador	385	Plumas	769
Butte	1,476	Riverside	5,152
Calaveras	595	Sacramento	3,043
Colusa	598	San Benito	476
Contra Costa	2,492	San Bernardino	7,030
Del Norte	346	San Diego	5,868
El Dorado	1,068	San Francisco	506
Fresno	3,824	San Joaquin	2,359
Glenn	831	San Luis Obispo	1,578
Humboldt	1,386	San Mateo	1,748
Imperial	1,889	Santa Barbara	1,507
Inyo	1,246	Santa Clara	3,891
Kern	4,569	Santa Cruz	673
Kings	691	Shasta	1,826
Lake	645	Sierra	294
Lassen	1,060	Siskiyou	2,363
Los Angeles	16,246	Solano	1,256
Madera	1,706	Sonoma	2,055
Marin	977	Stanislaus	2,194
Mariposa	612	Sutter	843
Mendocino	1,096	Tehama	628
Merced	1,660	Trinity	723
Modoc	947	Tulare	4,042
Mono	582	Tuolumne	685
Monterey	1,305	Ventura	2,133
Napa	701	Yolo	1,108
Nevada	672	Yuba	586
		GRAND TOTAL	113,409

Source: Roth, 1982.

Table 4.2-19

RESULTS OF REGRESSION ANALYSES OF COUNTY ROAD OIL AND CUTBACK USE
AND EMISSIONS VERSUS ROAD MILEAGE (X), 1980

Dependent Variable (Y)	Least-Squares Equation	Correlation Coefficient	95-pct Confidence Interval for Correlation Coefficient
All Counties (N=45)			
Road Oil Use (lb)	$Y = 171711 + 596X$	0.48	0.25, 0.67; $p < 0.05$
Cutback Use (lb)	$Y = 858275 + 71X$	0.09	-0.20, 0.35; $p > 0.05$
TOG Emissions From Road Oil Use (tons/yr)	$Y = 3.933 + 0.01X$	0.48	0.25, 0.67; $p < 0.05$
TOG Emissions From Cutback Use (tons/yr)	$Y = 55.809 + 0.0046X$	0.10	-0.21, 0.34; $p > 0.05$
Excluding Selected Urban Counties (N=43)			
Road Oil Use (lb)	$Y = -287167 + 653X$	0.52	0.22, 0.69; $p < 0.05$
Cutback Use (lb)	$Y = 436431 + 406X$	0.10	-0.24, 0.40; $p > 0.05$
TOG Emissions From Road Oil Use (tons/yr)	$Y = -4.377 + 0.011X$	0.52	0.22, 0.69; $p < 0.05$
TOG Emissions From Cutback Use (tons/yr)	$Y = 30.545 + 0.023X$	0.10	-0.24, 0.40; $p > 0.05$

4.2.4   Waste Recovery and Reclamation

Waste solvents are organic dissolving agents contaminated with sus-
pended and dissolved solids, organics, water, other solvents and/or sub-
stances. Reclamation is the process of restoring a waste solvent to a con-
dition that permits its reuse, either for its original purpose or for other
industrial needs. Much of the information presented in this section is con-
tained in Tiernay and Hughes (1978).

As solvent recycling becomes more cost effective, more and more
industries are reclaiming their own waste solvent.   Table 4.2-20 lists
industrial processes which employ solvent recycling.   In 1977, 114 million
tons of waste solvent were recycled nationwide.

On-site solvent recycling finds greatest application in lube oil and
wax manufacture, accounting for 88.7 percent of the nationwide total. Vege-
table oil manufacture and cleaning operations, which include degreasing and
dry cleaning solvent recycling, account for 8.8 and 2.0 percent of the total
nationwide recycling total, respectively. Eighty percent of all dry cleaners
and 20 percent of all degreasing operations recycle waste solvents. The major
process which will be discussed in this section will be off-site solvent
reclamation by private contractors, which accounts for 0.2 percent of the
nationwide total. Examining the process emission sites and the associated TOG
emissions from this independent industry will provide a general understanding
of similar process emissions from on-site solvent reclamation.   .

Most contract solvent reprocessors recover halogenated degreasing
solvents and/or aliphatics, aromatics and naphthenics such as those in the
paint and coating manufacturing industry. Table 4.2-21 is a list of solvents
commonly recycled by private contractors. As of 1977, 424 solvent reclaiming
operations were located in California, accounting for 10 percent of a nation-
wide total of 4,158 (excluding dry cleaning operations). The ARB has identi-
fied 20 firms in California which recycle solvents generated by other facili-
ties (Gin et al., 1982). The annual growth of the solvent recovery industry
is forecast at five percent and is predicted to become a billion-dollar-a-year
market by 1986, up from $200 million today (Tiernay and Hughes, 1978; Bry,

Table 4.2-20

INDUSTRIAL PROCESSES INCORPORATING SOLVENT
RECYCLING (NATIONAL FIGURES, 1977)

Process	Amount of Solvent Recycled (10^3 tons/year)	Percent of Total
On-Site Reclamation		
Lube oil and wax manufacture	101,412	88.7
Polymerization processes	276	0.2
Vegetable oil manufacturing	10,031	8.8
Metallurgical operations		
Pharmaceutical operations	25	<0.1
Cleaning operations	2,315	2.0
Off-Site Reclamation		
Solvent reclaimers (private contractors)	209	0.2
Totals	114,268	100.0

Modified from: Tiernay and Hughes, 1978.

Table 4.2-21
LIST OF SOLVENTS COMMONLY RECLAIMED BY PRIVATE CONTRACTORS[a]

Fluorocarbons	Methylene chloride
Perchloroethylene	Trichloroethylene
Hexane	Benzene
Toluene	Xylene
Mineral spirits	Naphthas
Acetone	Methyl ethyl ketone
Methyl isobutyl ketone	Cyclohexanone
Methanol	Ethanol
Isopropanol	Butyl alcohol
Amyl alcohol	Amyl acetate
Butyl acetate	Ethyl acetate

Source: Tiernay and Hughes, 1978.

[a] Total amount reclaimed by this industry = 209 x 10^3 tons.

1981). As disposal costs rise, as a result of the stringent requirements of the Federal Resources Conservation and Recovery Act, recycling is becoming a cost-effective alternative to disposal.

Figure 4.2-4 gives a process flow diagram for a typica solvent reclamation plant that reclaims 5,000 metric tons per year of waste solvent. Five basic recycling steps result in hydrocarbon emissions. Storage and handling activities create working emissions during the filling of large fixed or floating roof tanks. Initial treatment usually takes the form of activated carbon adsorption, absorption or mechanical separation. Emissions from this step occur during carbon regeneration or sludge draw-off. Waste solvents are then distilled to separate solvents from impurities. Emissions occur during condensation of solvent vapors and during sludge draw-off. Purification involves the separation of water by decantation or salting. Emissions during this step are fugitive. Disposal of waste sludge from initial treatment and distillation can be carried out by incineration, landfilling or deep-well injection. Eighty percent of all waste from recycling operations is incinerated. However, in the past, solvent reclaimers in California have not treated their own wastes (Garfield, 1982). Emissions occur during the incineration of distillation bottoms.

Table 4.2-22 reveals that, on a percentage basis, distillation emissions and fugitive emissions account for 77.8 and 21.4 percent, respectively, of all hydrocarbons emitted by processes at a solvent reclaiming plant. Emission factors for different sites at reclaiming plants are presented in Table 4.2-23. Data for establishing these emission factors were collected from source tests at one facility and from information provided by state air pollution control agencies.

4.2.5   Domestic Solvent Use

The ARB uses category of emission source (CES) number 46912 to cover general emissions from the use of cleaning compounds, floor waxes, cosmetics, health and beauty aids, and polishes in residential, institutional, and commercial establishments (Wong, 1982c). Although CES 58693 and 58701 cover "solvent" emissions from domestic use of aerosol sprays, the pollutant of concern
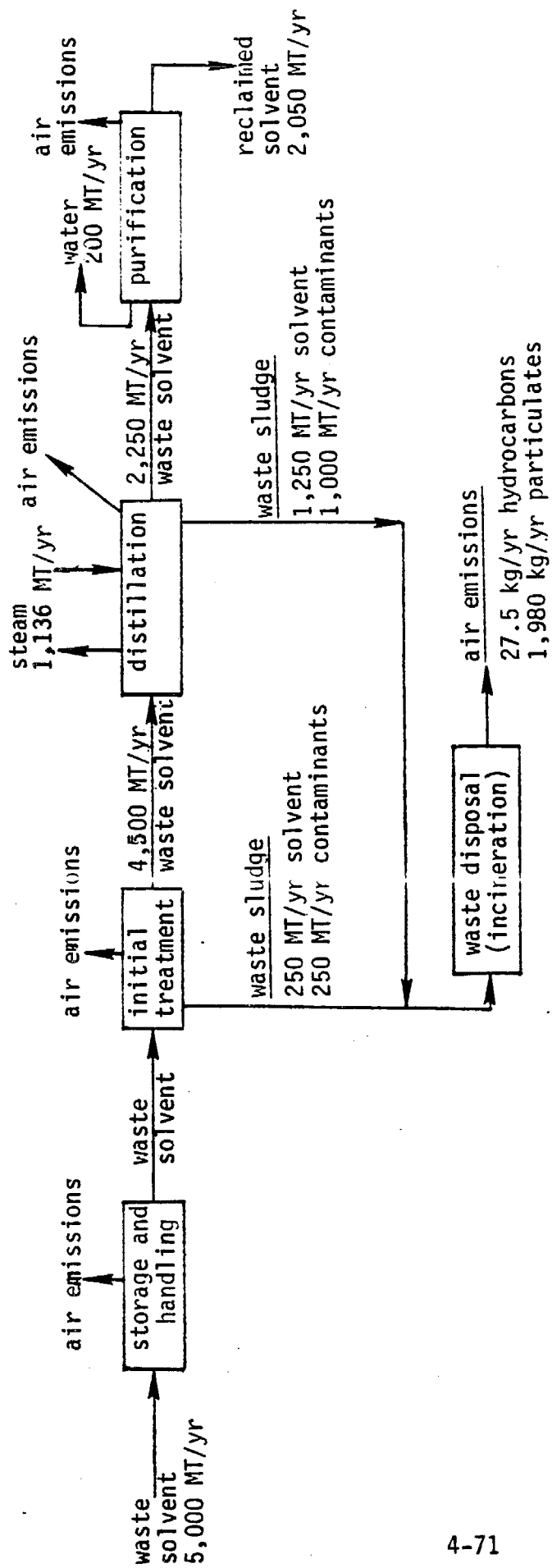
Figure 4.2-4. Process Flow Diagram for a Typical Solvent Reclamation Plant.

Source: Tiernay and Hughes, 1978

Table 4.2-22

TOTAL HYDROCARBONS EMITTED BY PROCESS OPERATIONS IN A
5,000 METRIC TON PER YEAR SOLVENT RECLAIMING PLANT

Operation		Hydrocarbons Emitted, %
Storage and handling		0.3
Distillation		77.8
Incineration		0.5
Storage and handling Initial treatment Purification	fugitive emissions	21.4

Source: Tierney and Hughes, 1978.

Table 4.2-23

HYDROCARBON EMISSION FACTORS FOR SOLVENT RECLAIMING[a]

Source	Emission Factor Range g/kg	Emission Factor Average g/kg
Storage tank vent[b]	0.002 - 0.04	0.0072 + 0.0038
Condenser vent	0.26 - 4.17	1.65 $\mp$ 1.38
Incinerator stack	0.01[c]	0.01[c]
Fugitive Emissions		
Spillage	0.095	0.095
Loading	0.00012 - 0.71	0.36 + 0.24
Leaks	NA	
Open source	NA	
Totals	0.38 - 5.0	2.1

Source: Modified from Tiernay and Hughes, (1978).

[a] Data obtained from state APCDs and pre-survey sampling. All emission factors are for uncontrolled process equipment except those for incinerator stacks.

[b] Storage tank is of the fixed-roof design.

[c] Only one available.

is the propellant gas (Linnard and Ipps, 1982), which is not of interest to the present study.

Estimation of solvent emissions is based upon an emission factor recommended by KVB, Inc. as part of a study of hydrocarbon emissions in the South Coast Air Basin (Taback et al., 1978). By using national sales figures for major product classes and (undocumented) estimates of their solvent contents, Taback et al. estimated a use and consequent emission of 1.1 tons per 1000 persons per year. This factor is multiplied by California's population to estimate emissions in this source category. As will be described in detail in Chapter 6, SAI made an independent estimate of organic solvent emission resulting from use of several of the domestic products considered by KVB. We also estimated emissions from use of some domestic products not considered by KVB, including household cleaners and pens.

Table 4.2-24 compares our estimates with those which went into calculation of the ARB's emission factor for this source category. KVB's values were calculated by multiplying the latest total source category estimate (24,966 tons/yr) by the ratio between KVB's estimate of national emissions of a source type (e.g. deodorant) and KVB's estimate of total national domestic solvent emissions. Although there is great uncertainty in any of these estimates, we believe that our estimates are more appropriate, since they are based upon verifiable assumptions and more recent market data. If our figures replace KVB's for the product types shown, then statewide emissions would decrease by 4,925 tons, or 20 percent. The emission factor would need to be changed to 0.88 tons per 1000 persons per year.

It should be noted that we did not include domestic emissions due to use of automotive products. As will be discussed in Section 6.4, about 9,155 tons of solvents are used in windshield cleaner antifreeze, gasoline drier, brake fluid and carburetor cleaner. To our knowledge, the EDS has no CES for emission of these solvents. Although considerably less than 100 percent of the solvent used would be emitted their inclusion in CES 46912 could alter the total emission estimate significantly.

Table 4.2-24

COMPARISON OF SAI's DOMESTIC PRODUCT EMISSION ESTIMATES
WITH THOSE USED FOR CES 46912

Product Category	KVB, Inc. Estimate (tons)[a]	SAI Estimate (tons)[b]	Recommended Change (tons)
Shaving cream	160	70	-90
After shave	532	1,526[c]	+994
Deodorant	1,118	70	-1,048
Nail polish	53	136	+83
Nail polish remover	373	400	+27
Rubbing alcohol	8,140	1,150	-6,990
Cleaners	-	1,371	+1,371
Pens	-	18	+18
Household adhesives	-	710	+710
Net Adjustment			-4,925

[a] Estimates from Taback et al., (1978) were adjusted so that statewide emissions equal 24,966 tons/yr for this source category.

[b] See Sections 6.2 and 6.4 for enumeration of solvent species comprising each category.

[c] Includes electric pre-shave lotion.

4.2.6   Surface Coatings

Point source emissions from the use of organic solvents in surface coatings are determined in different ways by the Bay Area and South Coast Air Quality Management Districts. Facilities reporting to the BAAQMD are instructed to specify the organic solvent content (percent by volume) and the solvent density of the coatings they use (BAAQMD, 1977). Furthermore, the species of the largest and second largest components of the solvents must be reported. The SCAQMD, in contrast, provides facilities with a list of organic solvent emission factors for enamel, lacquer and other coatings. Facilities may use emission factors of their own if they wish, but our EDS verification survey found that in the vast majority of cases, the District's recommended factors were used.

We believe that the Bay Area's approach is preferable, despite the increased burden it places upon reporting facilities. In deriving our own estimates of emissions for the facilities in our EDS verification survey we found that the actual solvent densities of enamels, lacquers, sealants and other coatings varied over quite a wide range. While the factors recommended by the SCAQMD may represent a reasonable average and thus be useful for estimating emissions for the entire South Coast Air Basin, errors for individual point sources could be significant. These errors, in turn, could affect the results of grid-based air quality models.

4.2.7   Pesticide Manufacture and Use

For several years concern over the use of pesticides has been directed towards their toxic effects on living species and the surrounding environment. The use of pesticides has now been implicated as a major contributor to volatile organic compound (VOC) emissions in California. Studies by Wiens (1977) and Leung et al. (1978) have reported that pesticide applications in rural, crop-producing areas in California may be one of the major potential sources of atmospheric hydrocarbons. Unless otherwise noted, information contained within this section was derived from Leung et al. (1980).

A pesticide may be broadly defined as any substance used to kill or retard the growth of insects, rodents, fungi, weeds or microorganisms. The composition of pesticides can be broken down into three basic categories: synthetic, nonsynthetic (petroleum products) and inorganic. Formulations are commonly made by combining synthetic materials with various petroleum products. The synthetic pest-killing compounds in such formulations are labeled "active" ingredients, while organic solvents, which serve as vehicles for the active ingredients, are labeled "inert." Neither designation is an indication of photochemical reactivity. In addition to their function as vehicles, organic fractions in synthetic formulations may also serve as synergists, inhibitors, wetting agents, stickers, perfumes and adjuvants. However, nonsynthetic hydrocarbons (NSHC) are used in greatest abundance in their pure form and are classified in the pesticide category - Formulation 10. Table 4.2-25 provides physical characteristics and major applications of NSHC pesticides.

Wiens (1977) estimates that California's total pesticide use in 1975 was 75.1 million and 241.7 million pounds for synthetic and nonsynthetic hydrocarbons, respectively. These results were obtained from data furnished by the California Department of Food and Agriculture's 1975 Pesticide Use Report (PUR) and information supplied by academic and industry sources. (Reporting of grower-applied NSHC pesticides in the PUR is not required; therefore the PUR gives an incomplete account of pesticide use in California.) Leung et al. (1980) estimate that 225.2 million pounds of NSHC pesticides were used in California in 1977. For this study, data from the California PUR and surveys of the pesticide manufacturers, dealers, growers, floriculturists, farm advisors, wood preservers and railroad operators were used to generate use figures. The application of NSHC pesticides in pure form (Formulation 10) accounted for 96.5 percent of the total, while 3.5 percent was applied as a minor ingredient in synthetic formulations. Table 4.2-26 provides a breakdown of Formulation 10 pesticide oil application by chemical. Petroleum hydrocarbons, petroleum oil (unclassified) and creosote account for 66.4, 12.5 and 12.2 percent of the total Formulation 10 use in California, respectively. Of the total state Formulation 10 use, 49 percent is used for miscellaneous weed control, 24 percent for farm applications and 12 percent for wood preservation.

Table 4.2-25

PHYSICAL CHARACTERISTICS OF NONSYNTHETIC HYDROCARBON PESTICIDE CHEMICALS

Chemical, Pesticide Type and Major Application	Percent Chemical Use in Oil Type[a]	Mean Boiling Point (^{0}F)	Mean Molecular Weight	Vapor Pressure (mm Hg at 20^{0}C)
Aromatic Petroleum Solvent				
Herbicide, Aquatic Weed Oil	100	279	110	6.50
Mineral Oil				
Insecticide, Fruit and Nut Oil Spray	100	690	327	7.4×10^{-6}
Petroleum Oil Unclassified				
Insecticide, Fruit and Nut Oil Spray	99.3	680	307	2.89×10^{-5}
Petroleum Distillate				
Insecticide, Mosquito Larvicide	100	571	253	9.11×10^{-4}
Petroleum Hydrocarbon				
Herbicide, Non Selective General Contact Herbicide and Defoliant	56.7	569	160	9.54×10^{-4}
Herbicide, Selective Oil for Carrot, Other Vegetables	43.3	350	124	0.546
Diesel Oil				
Herbicide, Solvent or Adjuvant			200	2.0×10^{-3}

[a] Based on usage reported in the 1977 Pesticide Use Report.

Source: Leung et al. (1980)

Table 4.2-26

FORMULATION 10 PESTICIDE OIL APPLICATIONS
BY CHEMICAL IN CALIFORNIA IN 1977

Chemicals	Pounds (10^6)	Percentage (%)
Aromatic petroleum solvent	0.83	0.4
Mineral oil	2.41	1.1
Petroleum distillates	3.04	1.4
Petroleum hydrocarbons	144.27	66.4
Petroleum oil unclassified	27.13	12.5
Diesel & creosote petroleum	13.15	6.0
Creosote	26.55	12.2
Total	217.38	100

Source: Leung et al. (1980)

The distribution of pesticide oil applications over time is particularly important for assessing potential air quality impacts. The month of greatest use occurs in April, accounting for 14.6 percent of the yearly total, followed by January (13.3 percent), June (12.0 percent) and August (10.6 percent). Of these, the August peak is of particular concern from an air quality viewpoint since the summer months are characterized by high ambient ozone concentrations in many parts of the state. Oil use in weed control applications accounts for the largest portion of pesticide oil use in California and has the greatest influence on temporal use patterns. For the months of January, April, June and August, petroleum hydrocarbons account for 60, 92, 78 and 54 percent of the monthly totals, respectively.

The spatial distribution of pesticide oil applications is also very important. In those areas where particularly high ozone concentrations occur, hydrocarbon emissions are of special concern. Table 4.2-27 gives a breakdown of pesticide oil used by the top 13 counties. In 1977, all of these counties were designated as ozone non-attainment areas. Seven counties are located in the San Joaquin Valley and two in the South Coast air basin; these two air basins have the greatest ozone problem in the state.

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Table 4.2-27

OIL PESTICIDE CONSUMED BY THE TOP 13
COUNTIES IN CALIFORNIA, 1977

County	Total Oil Used (10^6 lbs)	Percent of Total Statewide Use
San Joaquin	33.3	14.8
Monterey	29.6	13.1
Tulare	19.4	8.6
Kern	16.3	7.2
Fresno	14.5	6.4
Sacramento	13.9	6.2
Stanislaus	10.5	4.5
Imperial	10.1	4.5
Ventura	8.6	3.8
Merced	8.4	3.7
Los Angeles	8.0	3.6
Madera	6.5	2.9
San Bernardino	4.8	2.1
Subtotal	183.9	81.6
Statewide total	225.2	100.0

Derived from Leung et al. (1980)

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5.0

MARKET BALANCE METHODS

5.1   OVERVIEW OF THE METHODOLOGY

5.1.1   Purpose and Objectives

The purpose of the portion of the research to be described in the remainder of this report was to obtain an independent estimate of organic solvent use and emissions in California. The principal tool for this endeavor was to be the "market balance." A market balance (also known as a material balance) is an attempt to account for the origin and destination of every unit of mass of a substance; what cannot be accounted for as deliberate use and disposal may be assumed to enter the environment as air, water or soil pollution. Total solvent use and emissions would be the sums of the use and emissions of individual solvent species. SAI, through its subsidiary JRB Associates, Inc., had performed national materials balances on several organic chemicals, including many of the chemicals of interest. A study of methyl chloroform by Slimak et al. (1980) is an example.

Although a formal market balance had never been performed at the state level, it was believed at the start of the present project that such an undertaking would prove fruitful. At the very least, a firm estimate of the amount of various important organic solvents sold to California users and distributors would provide an upper bound to the amount eventually emitted to the atmosphere. It soon became apparent, however, that the belief on the efficacy of the market balance approach at the state level was unfounded. There were two reasons for this.

First, the flow of organic solvents through the state is so complex as to preclude a complete accounting. Over 100 chemical species are used as solvents, very often in mixtures whose composition is proprietary. Most of the important solvents are also used as feedstocks for other chemicals, and for other non-solvent uses. Furthermore, as our study revealed, approximately equal amounts of solvents are used directly (e.g. in degreasing and dry cleaning) as enter the state as ingredients in a myriad of industrial and consumer formulations (e.g. paints and household cleaners). Obtaining information on

sales of solvent chemicals to California was thus less useful than originally believed. In summary, tracing the use of any of the organic solvents of interest was both extremely difficult and subject to error.

The other difficulty with the market balance approach was the almost complete lack of California-specific data. Nationwide materials balance studies are made easier by the extensive availability of national production and consumption figures. As will be discussed further later in this chapter, no government agency or trade association collects data on the use of chemicals at the state level. Economic data which can serve as surrogates for chemical use are only occasionally broken down by state.

Given these obstacles to performing state-specific market balances, we abandoned the idea of determining emissions as the mass unaccounted for. Instead, we focused our attention upon the uses of organic solvents in the state, and, from the results of our use studies, estimated emissions directly. The following is a description of our approach.

5.1.2   Definitions

In order to impose some sort of order on this complex issue, we decided to distinguish between direct and indirect solvent use. Direct use consists of the application of individual solvents and/or solvent mixtures for the purpose of cleaning, thinning, or extracting. Example of direct solvent use are:

- Dry cleaning with perchloroethylene
- Industrial degreasing with 1,1,1-trichloroethane
- Addition, at a furniture plant, of toluene to paint
- Extraction of caffeine from coffee beans with a chlorinated solvent

Indirect use consists of application of a formulation which contains one or more organic solvents. The user may or may not know that the formulation contains solvents. Example of indirect solvent use include:

- Applying lacquer to furniture
- Use of a deodorant containing propylene glycol
- Application of an industrial adhesive containing hexane
- Application of nail polish

A type of use which could be interpreted to fall into either category is the manufacture of liquid products, such as ink, which contain solvents. The manufacturer uses solvents directly, in that they are added to the product, but when the product is subsequently used, the solvent use is indirect.

Another concept which had to be carefully defined was solvent availability. We defined it to be California production + imports to the state - exports from the state. Given the difficulty of ascertaining the values of any of the terms of this definition, the utility of the availability concept was quite limited. However, as will be seen below, it was useful in making preliminary estimates of the relative importance of various individual solvents.

5.1.3   Survey Approaches

Figure 5.1-1 shows our overall approach for determining market balance information, as well as other data of interest to the ARB. First, through a review of the literature, we identified roughly 100 solvent species and classes likely to be used in California. The next step was to make a preliminary estimate of the availability of each chemical for use as a solvent in the state. National production data were obtained from the SRI Chemical Economics Handbook (Anon., 1982c), the U.S. Department of Commerce, the U.S. International Trade Commission and from annual summaries in Chemical and Engineering News (e.g. Anon., 1982d). Two U.S. Environmental Protection Agency-sponsored studies, Organic Solvent Use Study (Lee et al., 1979) and Organic Chemical Manfuacturing (USEPA, 1980a), provided information on the nationwide distribution of each chemical among solvent and non-solvent uses (e.g. use as feedstock). From the production and the use pattern information, we then determined the amount of each solvent available nationwide for each solvent and non-solvent use. The next step was to identify the uses which actually occurred in California. In many cases, for example, chemicals for which the solvents of interest are also used as feedstocks are not manufactured in this state. Finally, solvent uses were apportioned to California with the following formula:

Figure 5.1-1. Schematic of Solvent e Data Collection Process
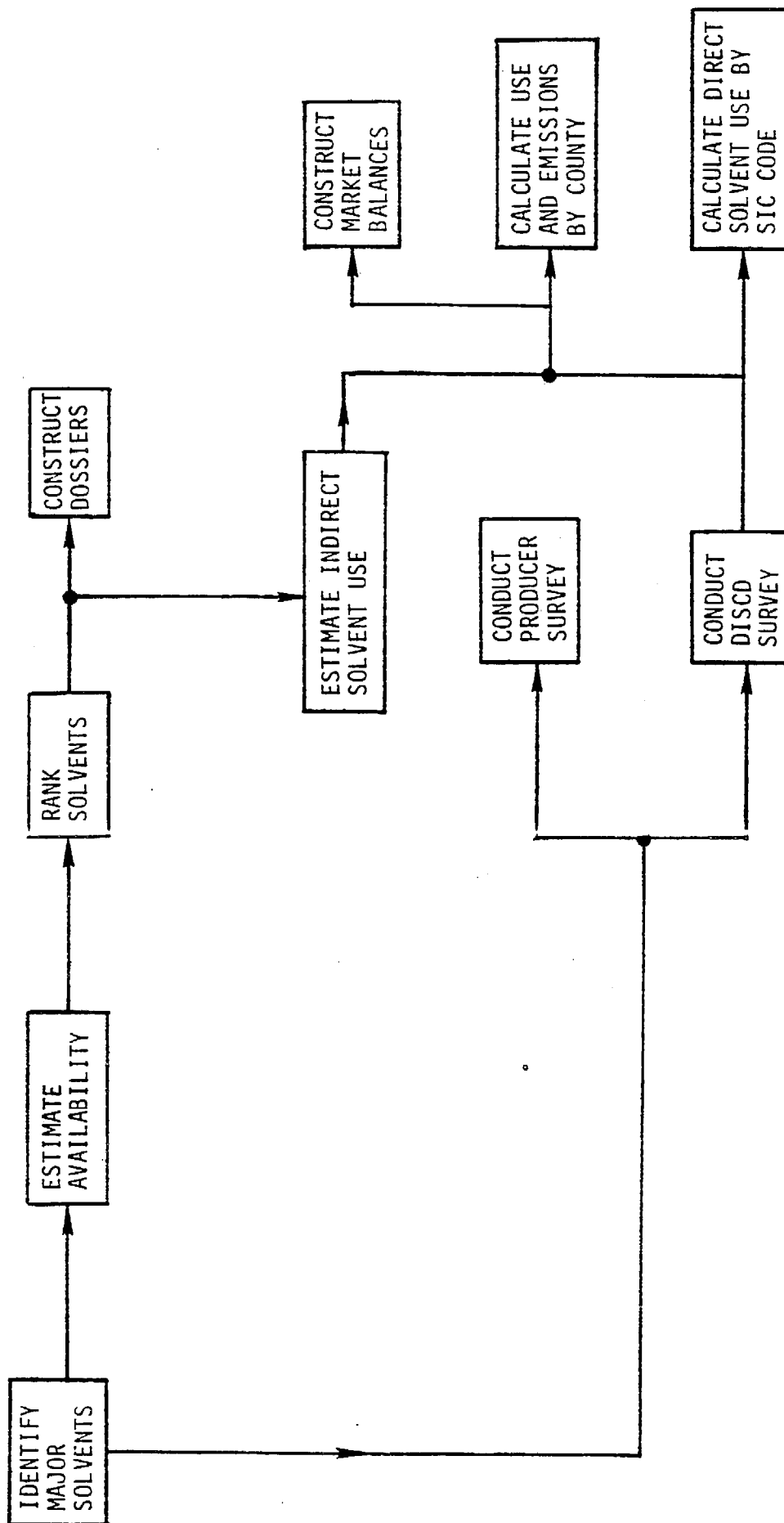
$$\text{California's Percent of National Use} = U_N \frac{\sum_{i=i}^{j} E_{C,i}}{\sum_{i=i}^{j} E_{N,i}} \qquad (5.1\text{-}1)$$

where U_N = total use of the chemical in the U.S. (lbs); and

        $E_{C,i}$, $E_{N,i}$ = the number of California and U.S. employees in SIC code i, respectively, where the chemical is used as a solvent; and

        j = number of SIC codes where chemical is used as a solvent.

If detailed solvent use information was unavailable, a gross California multiplier of 0.135, which represents the ratio of the number of California companies to U.S. companies in all manufacturing SIC codes (NBL, 1981), was used to apportion national figures. Finally, in some cases chemical companies which enjoyed the largest market share of a particular chemical provided estimates of California availability.

Preliminary estimates of availability were made for about 65 solvents. From more detailed studies of the most heavily-used solvents, 31 availability profiles were constructed. At that point in the project, it appeared that 20 solvents were responsible for over 90 percent of the total solvent use in the state. (Those chemicals are listed in Table 7.2-1.) It was these for which detailed market balance calculations were performed. As will be discussed in Section 7.4, it turned out that the 20 chemicals actually accounted for about 64 percent of our estimate of total California solvent use.

To obtain information on both direct and indirect solvent use, several information-gathering activities were conducted simultaneously. One was a mail survey of more than 6,500 facilities. Participants were asked to report the amount of each solvent species (or brand name mixture) purchased, incorporated in liquid products, recycled and disposed in Calendar Year 1980. Since this inquiry covered only direct use of solvents (i.e. not use of solvent-containing formulations such as as paints and adhesives), it was called the Direct Industrial Solvent Consumption and Disposal Survey (DISCD). A description of our survey methods is presented in Section 5.3. Two important

areas of direct solvent use were not covered by the survey. Dry cleaning was omitted because the EDS already contains a detailed point source inventory of dry cleaning plants. In addition, it was felt that, in order to adequately sample from among the over 1,800 dry cleaning facilities in the state, survey resources would have to be taken away from other industries which were not as well characterized. The other direct solvent use not surveyed was degreasing in gas stations, automobile repair shops, and other activities covered by the ARB Activity Code 300, "Services and Commerce." We believed that these types of degreasing had been covered adequately in previous ARB-sponsored research (see Section (4.2.2). In addition, adequate coverage of the over 10,000 automotive repair shops would not have been possible without reducing our coverage of other industries. It should be noted that a considerable amount of degreasing use in Activity Codes other than 300 was reported by our survey respondents.

In principle, the direct solvent consumption and disposal survey would provide an accurate estimate of the amount of each type of solvent entering the state. Before conducting that survey, though, we needed an alternative estimate, to serve as a "check" on the survey results. Several attempts to obtain California import data from government sources proved fruitless. According to our conversations with the U.S. International Trade Commission and the Bureau of the Census, import and export data are not available for individual states. Early in the study we applied to the Interstate Commerce Commission (ICC) for permission to examine its "one-percent waybill" sample, which is a random sample of shipments of commodities into, out of, and through a state by railroad. It was necessary to identify the Standard Transportation Commodity Code (STCC) for each chemical. This was done for all the solvents of interest, except for five which lack STCC codes. Unfortunately, the one-percent waybill sample we obtained included data on only one California shipment of a chemical of interest. The Association of American Railroads told us that it could supply data on the total number of shipments of specific commodities for the U.S. as a whole; origin- destination and volume data, however, were unavailable. In a final attempt to obtain rail shipment data, we contacted the Burlington Northern, Union Pacific, Western Pacific, and Atchison, Topeka and Santa Fe Railroads to see if they could supply us with information on their California operations. A representative of the Western Pacific Railroad replied that he could not (McClay, 1981). A problem with using data from

individual railroads was pointed out by a representative of the Burlington Northern, who said that transfer of shipments from his line to another line, once the shipments enter California, could lead to double counting, since the same shipment would appear on both railroads' records (Boyce, 1981). Furthermore, his railroad's data would most likely be at the two-digit STCC level, too general for our purposes.

About a third of the way through the project, we decided to conduct a survey of the producers of the solvents of interest. A description of the Producers Survey is presented in Section 5.2.

After the producers survey was underway, we made three more attempts to obtain California chemical sales data by other means. First, we contacted the Chemicals Division of the Department of Commerce's Bureau of Industrial Economics. According to one of the economists there, no one maintains statistics on individual states' consumption of chemicals (Rosse, 1982). Representatives of the Chemical Manufacturers Association (Anon., 1982a), Chemical Specialties Manufacturers Association (Davidson, 1982) and Synthetic Organic Chemical Manufacturers Association (Anon., 1982b) said that their organizations did not have data on state-specific sales of chemicals, and that they were unaware of any research in the area.

While the DISCD Survey and the producers survey were underway, we also investigated the use of organic solvents in formulations such as surface coatings and household products. Our methods and results are presented in Chapter 6. The results of the DISCD survey were used to estimate the use of various individual solvents by SIC code. Other results of that survey were combined with information gathered in our investigation of indirect solvent use to estimate total solvent use and emissions by county and air basin, and to construct market balances on 20 chemicals.

5.1.4   Market Balance Accounting

Figure 5.1-2 shows a typical result of our market balance calculations. Each box represents a temporary or permanent destination of a portion of the solvent entering the state. Above the horizontal dotted line, mass is

Figure 5.1-2. Example of Market Balance Summary (Acetone, values in 1000 pounds).

TOTAL DIRECT INDUSTRIAL SOLVENT USE
60,751 + 13,193
80,800*

TOTAL USE BY NON-FORMULATORS
36,549 + 7,505

POLLUTANT CONTROL
3,337 + 874

EMISSIONS
21,625 + 4,603

DISPOSE
9,077 + 1,775

RECYCLE
2,510 + 254

TOTAL USE BY FORMULATORS
24,202 + 5,688

DIRECT USE
406 + 34

EMISSIONS
256 + 28

POLLUTANT CONTROL
150 + 5

INCORPORATED IN PRODUCT
21,228 + 4,976

PROCESS EMISSIONS
425 + 100

NET USE AS INGREDIENT IN FORMULATIONS
20,803 + 4,876

TOTAL USE OF FORMULATIONS IN-STATE
15,512

EMISSIONS
13,836

POLLUTANT CONTROL
1,676

RECYCLE
2,425 + 629

DISPOSE
142 + 50

OUT-OF-STATE IMPORTS
y

EXPORTS
x

INDUSTRIAL MARKET BALANCE

INDUSTRIAL AND CONSUMER USE

TOTAL USE +
76,300

+ Total use = direct industrial solvent use
+ total use of formulations in-state

* total reported by chemical producers

conserved in the diagram, so that the sum of all the destinations downstream from a particular box must equal the amount in that box; below the dotted line, highly uncertain factors come into play, so that conservation of mass cannot be assured. Total solvent use of a chemical consists of the sum of the boxes labeled "Total Direct Industrial Solvent Use" and "Total Use of Formulations In-State."

The balance begins with two inputs to California. Total direct solvent use, which is reported in the uppermost box, was determined from our DISCO survey. Producer survey results are marked with an asterisk and shown in the same box for comparison with the market balance survey data.

For ease in interpretation of our DISCO results, we divided total use into two components. The first, total use by formulators, consists of use of the chemical as an ingredient in formulations such as paints, inks, and cosmetics. The remainder of the total use is accounted for by "non-formulators," which are those industries outside of the 2800-2999 range of SIC codes.

Formulators incorporate solvents in their products and may also use some solvents in plant operations, such as for cleanup. Additional amounts may be recycled and disposed. Thus the total use by formulators is split into incorporation in product, direct use, recycling and disposal. All the solvent used by non-formulators is assumed to be used directly. Not all the solvent intended to be incorporated in products actually is; some is lost to the atmosphere as process emissions. Emissions from direct use of solvents are assumed to be subject to some degree of abatement. That which is trapped and/or destroyed by pollution control devices is identified in the boxes labeled "pollutant control." Our methods for estimating process and direct use emissions are described in Section 5.4.

At this point in the balance, the direct use portion of total use has been completely accounted for (to the best of our ability to make estimates). Solvent purchased for the purpose of incorporation in products has also been accounted for; we must now determine the destination of the solvent which has actually made its way into formulations. It is here that the market balance process "breaks down." Some of the solvent-containing

formulations are used in California, while the rest is exported from the state. At the same time, formulations containing the same solvent of interest are imported by the state. There is no way to determine each of these quantities, short of requesting from the thousands of product formulators and distributors, both in California and in other states, detailed information on their sales to California wholesalers and retailers. In many, if not most cases, these data will be unavailable; even if they are, they are likely to be highly proprietary. Therefore, we did not use our estimate of net use in formulations any further in the market balance. Instead, we used the results of our separate investigation of indirect solvent use (Chapter 6) to estimate the total use of each chemical as an ingredient of formulations. This total use in formulations consists of the net use in products made in California ("Net Use as Ingredient in Formulations"), minus sales of California-made formulations to other states (x), plus sales of these formulations to California by out-of-state producers (y). The values of x and y cannot be known.

The accounting continues with estimation of emissions from the use of solvents in formulations. Again, emission estimation methods are described in Section 5.4. Finally, the total use of a given chemical in the state is defined as the sum of the direct industrial solvent use (top box) plus the "Total Use of Formulations in State." Estimates of recycling, disposal, emissions, and controlled pollutant mass are obtained by summing the values in the corresponding boxes.

5.2 SURVEY OF U.S. CHEMICAL PRODUCERS

As part of the solvent market balance study, it was necessary to determine the amount of solvent imported to and produced in California. With this information and data on national and California imports and exports, and the California solvent use and disposal survey, we were able to determine a probable upper bound for predictions of solvent emissions.

5.2.1 Sources of Names

The names and addresses of solvent producers and the chemicals they manufacture are identified in the SRI Chemical Economics Handbook. Other

minor sources were consulted to insure that our list was complete. These included:

- Organic Chemical Manufacturing, Vol. 6-10 (USEPA, 1980a);

- Chem Sources - USA (Anon., 1981a); and

- Chemical Week Buyers' Guide (Anon., 1981b).

A list of 85 chemical producers was assembled. These companies were found to manufacture a combined total of 56 chemicals which are either used almost entirely, partially or rarely as a solvent.

5.2.2 Survey Procedure

A form letter (Figure 5.2-1) modified for each company was sent to the attention of the marketing director. In each letter, the chemicals which we believed the company to produce were identified. Companies were asked to give the amounts of these chemicals they manufactured and shipped to California end users and distributors in calendar year 1980. Enclosed with each letter was a list of 60 commonly used solvents. The producers were instructed to review the list and add any other solvents which were not on our company-specific list.

If a response was not received within a month, follow-up telephone calls were made to obtain the name and proper address of the appropriate person within the chemical company. A second survey was then mailed. It was determined later that with a survey of this size, turnaround time would be shortened if the names of company contacts were established at the beginning of the survey so that a general addressee of "Marketing Director" would not be needed.

5.3 DIRECT INDUSTRIAL SOLVENT CONSUMPTION AND DISPOSAL SURVEY
5.3.1 Identification of Firms

The first step in identifying firms to which to send the surveys was to select relevant Standard Industrial Classification (SIC) codes. Lamason

Marketing Director
Company Name
Address

Dear Sir:

Science Applications, Inc. (SAI) would like your help in a research project we
are conducting for the California Air Resources Board (CARB). The CARB and
local air pollution control districts maintain emission inventories which keep
track of various types of air pollutant emissions from thousands of stationary
sources in California. Because these emission data bases are used in new source
reviews and in predicting air quality trends, it is essential that they be
up-to-date and accurate.

The purpose of our study is to verify the accuracy of those portions of the
statewide emission inventory which cover use of organic solvents. Our main
approach will be to perform a "market balance" on several organic solvents. If
we can determine how much of a given solvent compound is produced in California,
imported from other states and abroad, and exported to other states and abroad,
then we can, along with other data, establish a probable upper bound for
predictions of solvent emissions. Other parts of our study include surveys of
solvent use and disposal in the state.

It is our understanding that your company manufactures methyl ethyl ketone,
n-butyl alcohol and acetone, which are used in part or largely as solvents. It
would be of great assistance to our study if you could tell us how many pounds
of these compounds, or any other chemical you find on the enlosed list, you sold
to California distributors or users in Calendar Year 1980. Please be assured
that the information you give us will be kept in strict confidence. Any reports
available to the public will contain statistical summaries only, and will
neither identify individual firms nor provide information from which their
identities may be inferred. Attached are copies of our authorization letter
from the CARB, a list of additional chemicals, and the secrecy agreement which
we have signed with that agency. If you feel that any information you report to
us should be deemed a trade secret, please so state.

By assisting us in this survey, you will help ensure that air pollution
regulation in California is based upon the most accurate information. As a side
benefit, you will be able to obtain, from our summary results, an improved idea
of the market for your products in the state.

The CARB Research Contract Monitor for this project is Mr. Joseph Pantalone, who
may be reached at (916) 323-1535. If you have any questions about our request,
please contact me at the address shown below, or call me at (213) 553-2705.

Sincerely,

SCIENCE APPLICATIONS, INC.

Michael B. Rogozen, D. Env.
Principal Investigator
CARB Emission Inventory Project

Figure 5.2-1. Example of the Cover Letter Sent to Chemical Producers.

and Lahre (1980) list 22 two-digit and 53 four-digit SIC codes in which solvents are commonly used. That list was expanded by perusing an ARB computer printout which showed which SIC codes were normally associated with which solvent-using EPA Source Classification Codes (SCCs). Our preliminary list consisted of 252 SIC codes.

Because it would not have been practical to survey firms under all of these codes, it was necessary to eliminate a large number of them. We therefore conducted our survey in three phases. While the purpose of the first phase was primarily to test the utility of our questionnaire (see below), we obtained enough information on some industries to show that they were only minor solvent users. Our objective in the second phase was to send questionnaires to ten randomly-selected firms in each SIC code, in order to ascertain which were likely to be the highest users. Although this phase was truncated, we were able to eliminate many more codes from consideration. A list of codes reported by survey respondents is provided in Table 5.3-1. SIC codes marked with an asterisk were those chosen for the third phase of the survey. The reader should refer to Table 5.3-1 for definitions of SIC codes when they are discussed elsewhere in this report.

Names. addresses. and telephone numbers of firms to be surveyed were obtained from four sources. We began with manual searches of the 1980 California Manufacturers Register (CMA, 1980) and the Dun and Bradsteet Industrial Directory. Neither of these sources was particularly useful. Inclusion in the former is voluntary, so that the majority of firms in many SIC codes are not listed, while the latter contained an intolerable number of errors. The most vexatious error was misclassification by SIC code. Many addresses were also incorrect. A third data source was the EPA San Francisco Regional Office, which provided us with names and addresses of about 300 firms from a survey it had recently conducted (Henderson, 1981). Unfortunately, most of the SIC codes in this data set corresponded to very minor solvent users.

Our fourth and most important source of names and addresses was a mailing label set provided by National Business Lists, Inc. (NBL) of Chicago, Illinois. Labels were organized first by SIC code and then in increasing order of zip code. NBL and other such mailing list companies claim to update

Table 5.3-1

STANDARD INDUSTRIAL CLASSIFICATION (SIC) CODES USED
IN DIRECT SOLVENT CONSUMPTION SURVEY
(Asterisks denote codes chosen for Phase III survey)

Code	Description
2032	Canned specialties
2044	Rice milling
2045	Blended and prepared flour
2048	Prepared feeds, NEC[a]
2079	Shortening and cooking oils
2086	Bottled and canned soft drinks
2095	Roasted coffee
2099	Food preparations, NEC
2271	Woven carpets and rugs
2291	Felt goods, except woven felts and hats
2295	Coated fabrics, not rubberized
2342	Brassieres and allied garments
2434	Wood kitchen cabinets
2435	Hardwood veneer and plywood
2436	Softwood veneer and plywood
2451	Mobile homes (wood)
*2511	Wood household furniture, except upholstered
*2512	Wood household furniture, upholstered
*2514	Metal household furniture
*2515	Mattresses and bedsprings
*2517	Wood, TV, radio, phonograph, sewing machine cabinets
*2519	Household furniture, NEC
*2521	Wood office furniture
*2522	Metal office furniture
*2531	Public building and related furniture
*2541	Wood partitions, shelving, lockers, office and store fixtures
*2542	Metal partitions, shelving, lockers, office store fixtures
*2591	Drapery hardware and window blinds shades
*2599	Furniture and fixtures, NEC
*2641	Paper coating and glazing
2643	Bags, except textile bags
2647	Sanitary paper products
2648	Stationery products
2649	Converted paper products, NEC
2651	Folding paperboard boxes
2653	Bags, except textile bags
2711	Newspapers
*2751	Commercial printing, letterpress and screen
2752	Commercial printing, lithographic
*2753	Engraving and plate printing
*2754	Commercial printing, gravure
2791	Typesetting
*2812	Alkalies and chlorine
*2813	Industrial gases
*2816	Inorganic pigments
*2819	Industrial inorganic chemicals, NEC
*2821	Plastics materials, synthetic resins, non-vulcanizable elastomers
*2822	Synthetic rubber (vulcanizable elastomers)
*2823	Cellulosic man-made fibers
*2824	Synthetic organic fibers, except cellulosic
2831	Biological products
*2833	Medical chemicals and botanical products
*2834	Pharmaceutical preparations
*2841	Soap and other detergents, except specialty cleaners
*2842	Specialty cleaning, polishing, and sanitation preparations
*2843	Surface active agents, finishing agents, sulfonated oils and assistants
*2844	Perfumes, cosmetics, and other toilet preparations
*2851	Paints, varnishes, lacquers, enamels, and allied products
*2861	Gum and wood chemicals
*2865	Cyclic (coal tar) crudes, and cyclic intermediates, dyes, and organic pigments (lakes & toners)
*2869	Industrial organic chemicals, NEC
*2879	Pesticides and agricultural chemicals, NEC
*2891	Adhesives and sealants
*2892	Explosives
*2893	Printing ink

[a] NEC = Not elsewhere classified.

their lists with the issuance of each new edition of the telephone directories corresponding to the geographical areas covered. Nevertheless, about nine percent of the addresses we used were incorrect. However, the use of a mailing label service was significantly more cost-effective than our manual searches.

For SIC codes containing 30 or fewer firms, questionnaires were sent to all the companies. For the other SIC codes, a computer program having a random number algorithm selected firms such that the probability of any one firm being chosen was 2/3. As will be described below, other methods were used to choose additional firms later in the survey.

5.3.2 Data Requested

Each firm in the survey was mailed a package consisting of a cover letter, an explanatory letter from the Chief of the ARB's Research Division, and secrecy agreement between SAI and the ARB, a three-page questionnaire, and a list of common solvents. A sample package is included in Appendix A. The questionnaire form is shown in Figure 5.3-1.

Firms were asked for both their total number of employees and the number actively engaged in the solvent-using activities or services. These values were each needed for a different method of extrapolating survey results (see below). In the first phase of our survey, the form included the names of 25 common solvents. In the final version, we left it to the respondents to fill in the names of the solvents they used, since (1) we didn't know at the beginning of the study which solvent species were the most important in the state and (2) many respondents could identify only the brand names of the solvent formulations they used.

Respondents were asked to report the amount of each type of solvent they purchased in 1980. (For this reason, surveys were sent to the "purchasing agent" for each firm.) We felt that this question would be less ambiguous than if we had asked how much solvent was "used" or "consumed." Since some of the major solvent compound users, such as those in SIC 2851 (paint and coatings manufacturing), use solvents mainly as ingredients in formulations, we

Table 5.3-1

STANDARD INDUSTRIAL CLASSIFICATION (SIC) CODES USED
IN DIRECT SOLVENT CONSUMPTION SURVEY
(Continued)
(Asterisks denote codes chosen for Phase III survey)

Code	Description
*2895	Carbon black
*2899	Chemicals and chemical preparations, NEC
*2911	Petroleum refining
*2951	Paving mixtures and blocks
*2952	Asphalt felts and coatings
2992	Lubricating oils and greases
*2999	Products of petroleum and coal, NEC
*3011	Tires and inner tubes
*3021	Rubber and plastics footwear
*3031	Reclaimed rubber
*3041	Rubber and plastic hose and belting
*3069	Fabricated rubber products, NEC
*3079	Miscellaneous plastics products
*3111	Leather tanning and finishing
3231	Products of purchased glass
3339	Primary nonferrous metals, NEC
3361	Aluminum foundries
*3411	Metal cans
*3412	Metal shipping barrels, drums, kegs, and pails
*3421	Cutlery
*3423	Hand and edge tools, except machine tools and hand saws
*3425	Hand saws and sawblades
*3429	Hardware not elsewhere classified
*3431	Metal sanitary ware
*3432	Plumbing fittings and brass goods
3441	Fabricated structural metal
3442	Metal doors, sash and trim
3444	Sheet metal work
3452	Bolts, nuts, rivets and washers
·3471	Plating and polishing
*3479	Metal coatings and allied services
3498	Fabricated pipe and fittings
*3541	Machine tools, metal cutting types
*3542	Machine tools, metal forming types
3544	Special dies, tools, jigs and fixtures
3569	General industrial machinery, NEC
3589	Service industry machinery, NEC
3599	Machinery except electrical, NEC
*3631	Household cooking equipment
*3632	Household refrigerators and freezers
*3634	Electric housewares and fans
*3639	Household appliances, NEC
3662	Radio and TV communication equipment
3674	Semiconductors and related devices
3679	Electronic components, NEC
3699	Electrical equipment and supplies, NEC
*3711	Motor vehicles and car bodies
*3713	Truck and bus bodies
*3714	Motor vehicle parts and accessories
*3715	Truck trailers
*3721	Aircraft
*3724	Aircraft engines and engine parts
*3728	Aircraft equipment, NEC
*3731	Ship building and repairing
*3732	Boat building and repairing
*3743	Railroad equipment
*3751	Motorcycles, bicycles and parts
*3761	Guided missiles and space vehicles
*3764	Guided missiles and space vehicle propulsion units
*3769	Guided missile and space vehicle parts, NEC
*3792	Travel trailers and campers
*3795	Tanks and tank components
*3799	Transportation equipment, NEC
3811	Engineering, laboratory, scientific and research instruments
3822	Environmental controls
*3832	Optical instruments
3841	Surgical and medical instruments
*3842	Orthopedic, prosthetic, and surgical
*3851	Ophthalmic goods
*3861	Photographic equipment and supplies
3949	Sporting and athletic goods, NEC
3961	Costume jewelry
3999	Manufacturing industries, NEC
4511	Air transportation
7819	Services allied to motion pictures.

Source: SRI, 1980.

SCIENCE APPLICATIONS, INC./CALIFORNIA AIR RESOURCES BOARD

SOLVENT USE AND DISPOSAL QUESTIONNAIRE

Firm _____

SIC _____

_____

_____

INSTRUCTIONS

<u>Note</u>: If your firm has no manufacturing facilities in California, please check here ☐ and return the questionnaire in the attached envelope. Thank you.

1. Please fill in one section of this form for each Standard Industrial Classification (SIC) code relevant to your operations. If you don't know your code(s), then briefly describe your product or service and we will determine the SIC number.

2. List all solvents you purchased for your operations and incorporate in your products. The attached list gives examples of the solvents commonly used in California. If your solvent type is not on the list, please report it anyway; we need to identify and quantify as many as possible. If you do not know the chemical name of the solvent, then please report the brand name and type (for example, Chevron 1200).

3. Give amount of solvent purchased for your operations and incorporated in your products in Calendar Year 1980. Specify whether amount is in pounds or gallons.

4. Indicate the means by which you dispose of the solvents you use; give the amounts of solvent disposed in Calendar Year 1980.

SIC Code (if known) _____ Type of Product or Service _____

No. of personnel engaged in this type of production or service (do not include administrative personnel) _____

Total number of personnel at your facility _____

<u>Amount Disposed of in 1980</u>

Name of Solvent	Amount Purchased for 1980 Operations	Amount Incorporated in Product	To Solvent Recycler	On-Site or Off-Site Disposal
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

Figure 5.3-1. Questionnaire for Direct Solvent Consumption and Disposal Survey.

SIC Code (if known) _____ Type of Product or Service _____

No. of personnel engaged in this type of production or service (do not include administrative personnel) _____

Total number of personnel at your facility _____

Amount Disposed of in 1980

Name of Solvent	Amount Purchased for 1980 Operations	Amount Incorporated in Product	To Solvent Recycler	On-Site or Off-Site Disposal
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

SIC Code (if known) _____ Type of Product or Service _____

No. of personnel engaged in this type of production or service (do not include administrative personnel) _____ __

Total number of personnel at your facility _____

Amount Disposed of in 1980

Name of Solvent	Amount Purchased for 1980 Operations	Amount Incorporated in Product	To Solvent Recycler	On-Site or Off-Site Disposal
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

Figure 5.3-1. Questionnaire for Direct Solvent Consumption and Disposal Survey. (Cont.)

SIC Code (if known) _____ Type of Product or Service _____

No. of personnel engaged in this type of production or service (do not include administrative personnel) _____

Total number of personnel at your facility _____

Amount Disposed of in 1980

Name of Solvent	Amount Purchased for 1980 Operations	Amount Incorporated in Product	To Solvent Recycler	On-Site or Off-Site Disposal
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

5. Please state name and phone number of person to contact for more information.

_____

6. Thank you for your assistance. Questionnaires should be returned as soon as possible to:

Science Applications, Inc.
1801 Avenue of the Stars, Suite 1205
Los Angeles, California 90067
Attention: ARB Emission Inventory Project

Figure 5.3-1. Questionnaire for Direct Solvent Consumption and Disposal Survey. (Cont.)

asked how much solvent was incorporated in the company's product. Responses had to be scrutinized carefully, since some respondents confused application of a solvent-containing compound to an item (e.g. adding lacquer thinner to lacquer and then applying the coating to an item of furniture) as incorporation of the solvent in their product. Several follow-up calls were made to determine the actual fate of the solvent. When large quantities of solvent recycling were reported, we contacted the respondent to determine whether the recycling was on- or off-site. Disposal was the most difficult item to interpret. Often respondents reported where they disposed of the solvents (e.g. "down the sewer" or "throw away rags") but not how much. We decided to count only major quantified off-site disposal. thus our estimates of disposal will probably be on the low side.

Most of the respondents reported volumes rather than masses of solvents. It was therefore necessary to multiply volumes times specific weight or densities to obtain masses. Density data for all individual solvent species were available from various chemical reference books and from manufacturers. To obtain density data for brand-name solvents, we contacted all major manufacturers. Since data on brand-name solvent composition and density are of general interest to the ARB, we have provided a compilation thereof (Appendix C) under separate cover (Rapoport et al., 1983).

5.3.3   Data Base Management

All survey data storage, and most computations, were carried out on an Apple II Plus[TM] microcomputer having two disk drives and 48 kilobytes of random access memory. Three sets of floppy diskette files were used. The Status Files contained names, addresses, telephone numbers and SIC codes of all the firms contacted. Two files kept track of the status of the questionnaire and the date of the last change in status. As each survey form was returned, the date and status codes were updated and any other necessary data revisions were made. From time to time, the Status Files were searched for those firms which had not yet responded, and lists of names and telephone numbers (for follow-up calls) were generated.

Responses to the survey were stored in the Results Files. One random access file was set up for each survey parameter (total use, active employees, etc.). A file of survey identification numbers, whose file positions corresponded to the record numbers of values in the results files, was also maintained. Figure 5.3-2 shows how the Results Files were organized.

Finally, Chemical Results Files were set up for 44 major chemical species and formulations. Each file contained records on SIC code, total employees, and amounts purchased, incorporated in product, recycled and disposed. Supplementary files on 26 relatively low-use solvents were set up and maintained manually.

Since no commercial data base management system was deemed flexible enough for our needs, original software for data storage and retrieval, searches, updates, calculations and reports was written in Applesoft BASIC. Computer graphics for this report were generated with the Visiplot (Personal Software, Inc., Sunnyvale, CA) and Scientific Plotter (Interactive Microware, Inc., State College, PA) packages.

5.3.4   Survey History

Phases I and II were conducted during August - October 1981 and November 1981 - March 1982, respectively. Mailing of the 5,900 questionnaires in our original Phase III set began on 1 April 1982 and continued until 26 July 1982. About 25 percent of the questionnaires comprising this first mailing were returned. The actual response rate was even lower, since an alarmingly high percentage of the returns consisted of wrong addresses.

Realizing the need to obtain a much higher real response rate, we decided to make follow-up telephone calls to firms in those Phase III SIC codes which had the highest direct solvent use. To identify these industries, we used the following "scale-up" formula for each SIC code:

$$U_{P,i} = \left(\frac{N_{C,i}}{N_{S,i}} \right) U_{S,i} \qquad (5.3\text{-}1)$$
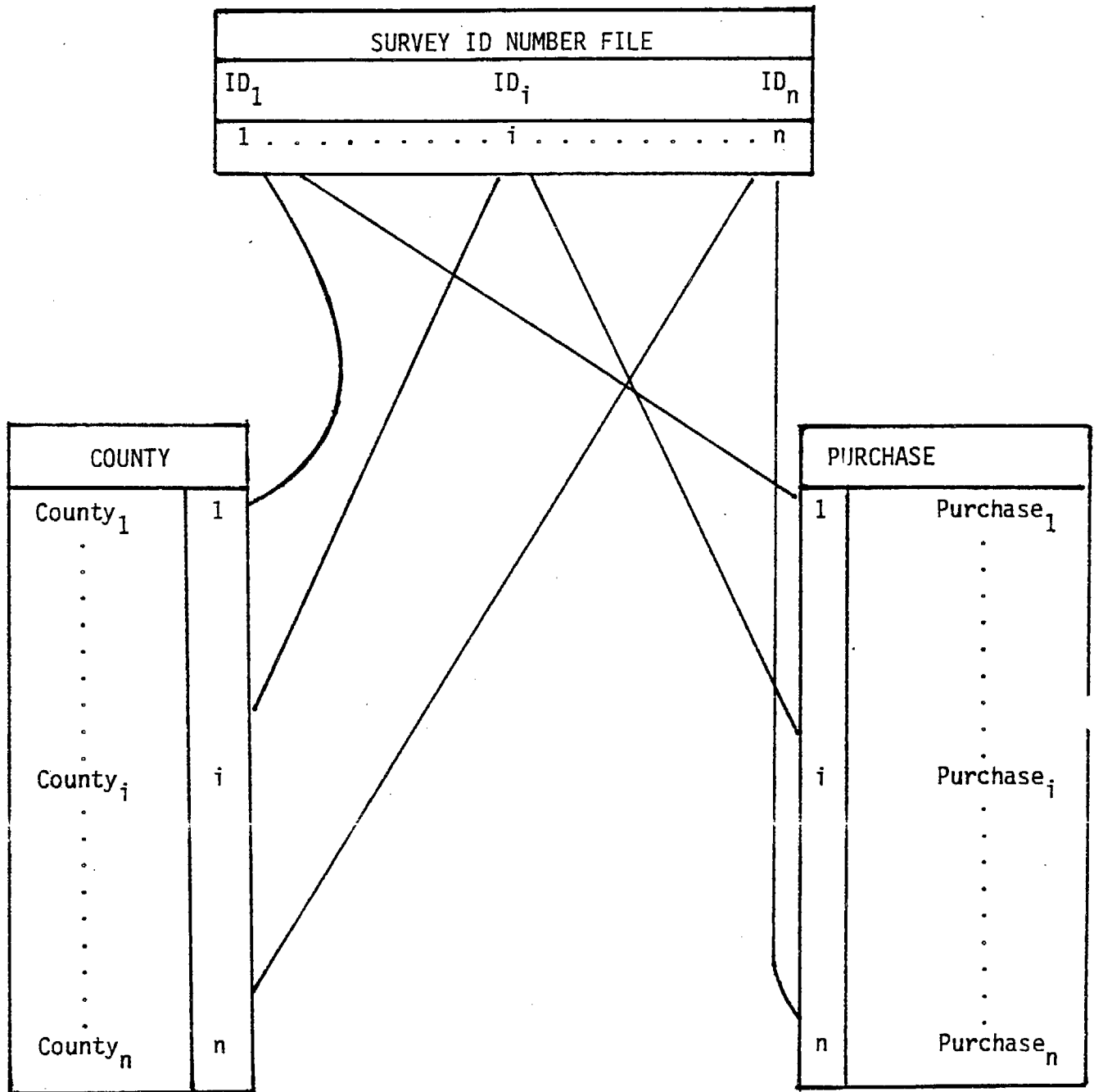
Figure 5.3-2.   Results File Structure, Showing How
Data for Individual Firms are Retrieved.

where $N_{C,i}$ and $N_{S,i}$ are the number of firms in California and in our survey for SIC code i; $U_{S,i}$ is the total solvent use reported in our survey for the ith SIC code, and $U_{p,i}$ is the projected total use for that SIC code. Using this formula on our results as of July 1982 led us to the discovery that only seven SIC codes (2821, 2822, 2831, 2851, 2869, 2879, and 2899) accounted for about 90 percent of the total projected solvent use. Although consideration of data received later in the study resulted in a downgrading of the importance of this group of industries (to about 60 percent of the state's direct solvent use), we sent questionnaires to those firms not originally chosen by the random selection program. For many SIC codes, all known firms were contacted. We also began telephoning the nonresponding firms. In many cases our survey had not reached the appropriate person and had been discarded. New survey forms were sent to those companies. Many firms gave us complete information over the telephone.

Early in September 1982, after considerable success with our telephoning, we were able to identify 17 combinations of SIC code and county where direct solvent consumption was likely to be highest. Examples were SIC 2822 in Los Angeles County, and SIC 2992 in Orange County. Additional questionnaires were mailed where necessary, and our telephoning continued.

At least some information was obtained from about 30.1 percent of the 6,222 firms to which the Phase III survey was sent. Complete information on individual solvent species use was obtained for 15.6 percent of the firms. Only 47 firms (less than 1 percent) refused to cooperate. One factor contributing to the low response rate was that 538 firms had gone out of business or had moved out of California since NBL had compiled its mailing list. These firms were presumed to have been in business in 1980, though their characteristics cannot be known. The data base for our calculation of solvent use and emission consisted of 972 responses from this survey, plus 182 responses from the Phase I, Phase II and EDS Verification surveys, for a total of 1,154.

5.3.5   Scaling Up From the Survey Results

Since a 100-percent response to our direct industrial solvent consumption survey was impossible to obtain, it was necessary to scale up our

sample results to the state as a whole. Our method is based upon the realization that we have a stratified sample of California industry. The U.S. Bureau of the Census publication County Business Patterns (U.S. Department of Commerce, 1979b) shows, for every California county, the distribution of firms by SIC code and number of employees. The SIC code and county were known for each firm in our survey, and participants were asked to report their total number of employees. It was therefore possible to place each responding firm in a "cell" defined by its county, SIC code and size. We then assumed that the non-responding firms in each cell had the same average solvent use per firm as did the respondents. The basic scale-up equation is:

$$C_{ijk} = \left(\frac{U_{ijk}}{R_{ijk}}\right) N_{ijk} \qquad (5.3\text{-}2)$$

where U_{ijk}, R_{ijk}, and N_{ijk} are the total reported use, number of respondents, and number of firms (as reported in County Business Patterns) for a cell defined as the combination of county i, SIC code j and firm size class k. C_{ijk} is then the estimated total use for that cell.

Table 5.3-2 shows two examples of the scale-up method. In Case A, all the respondents in Los Angeles County and having SIC code 2851 reported their number of employees. C_{ijk} was therefore calculated directly for each of the nine firm size classes. Case B is an example of a situation in which one or more firms reported zero solvent use without telling us their number of employees. Follow-up calls were made to as many of these firms as possible, but we could not contact all of them. The problem in Case B is that we do not know the size class(es) into which the two zero-use firms fall. Our solution was to assume that they were distributed evenly among the size classes ranging from number one to the largest for which we have data. In this case, the 2 firms would be distributed among classes 1 through 4; i.e. 0.5 would be added to R_{ijk} for those four classes. Equation 5.3-2 was used with the adjusted values of R_{ijk} to obtain the adjusted value of total consumption, C'_{ijk}.

Consumption totals for cells could be summed in several ways. To obtain the total consumption for SIC code j, T_j, we let

Table 5.3-2

EXAMPLES OF "SCALE-UP" CALCULATIONS

Case A: SIC 2851 in Los Angeles County

Size Class	N	R	U (lb)	C (lb)
1	18	6	521,316	1,563,948
2	13	8	2,348,953	3,817,049
3	24	7	242,850	832,629
4	28	6	6,960,705	32,483,290
5	16	3	14,259,463	76,050,469
6	7	1	288,440	2,019,080
7	1	0	0	
8	1	0	0	
9	0	0	0	
	108	31	24,621,727	116,766,465

Case B: SIC 3079 in Riverside County

Size Class	N	R	U (lb)	C (lb)	C' (lb)
Unknown	0	2	0	0	0
1	10	1	48	480	320
2	4	0	0	0	0
3	4	1	344	1,376	917
4	4	1	524	2,096	1,397
5	3	0	0	0	0
6	3	0	0	0	0
7	0	0	0	0	0
8	1	0	0	0	0
9	0	0	0	0	0
	29	5	916	3,952	2,634

$$T_j = \sum_{i=1}^{58} \sum_{k=1}^{9} C_{ijk} , \qquad (5.3-3)$$

since there are 9 size classes and 58 counties. To obtain the total consumption for a county, t_i, we let

$$(5.3-4) \qquad T_i = \sum_{j=1}^{n_j} \sum_{k=1}^{9} C_{ijk}$$

where n_j is the number of applicable SIC codes. Finally, the total solvent consumption for the state, T, is found from

$$T = \sum_{i=1}^{58} \sum_{j=1}^{n_j} \sum_{k=1}^{9} C_{ijk} \qquad (5.3-5)$$

In order to obtain a range of estimates of total solvent consumption, we performed the above calculations using C_{ijk} and C'_{ijk}. We also made a third estimate, T_{ij}, which is the total consumption for SIC code i in county j. This value is defined as:

$$T_{ij} = \sum_{R_{ij}}^{U_{ij}} N_{ij} \qquad (5.3-6)$$

where U_{ij}, R_{ij} and N_{ij} are the total reported uses, total reporting firms and total number of firms for SIC code i in county j. For example, in Case B, U_{ij} = 916, R_{ij} = 5 and N_{ij} = 29. Therefore T_{ij} = 5,313.

Use of the above procedures results in two estimates if the sizes of all reporting firms are known, and three estimates if the C'_{ijk} must be calculated. Values presented in this report represent the midpoint between the low and high estimates. Where uncertainty is reported, it is defined as the difference between the midpoint and the low value. For example, in Case B, the

midpoint is (2,634 + 5,313)/2 = 3,974. The uncertainty is $\pm$ 1,340 (33.7 percent).

The level of disaggregation used in the foregoing calculation assures us that our scale-up is reasonable. It should be noted that the process illustrated was used only for calculating total use and emissions for each county. To reduce the considerable effort involved in this sort of computation (even when one uses a computer), total use and emissions by SIC code and by chemical species were done for the state as a whole, and not county-by-county. To do this, we used a summary table in County Business Patterns which listed statewide firm size distribution by SIC code.

5.4   EMISSION ESTIMATION METHODS

Until now the focus of our discussion has been upon solvent use, rather than emissions; indeed, a major objective of this project was to delineate patterns of solvent use in California. Nevertheless, in order to use our market balance information as a check on the EDS, it was necessary to estimate emissions from:

- Direct industrial solvent use, as determined by our direct industrial solvent consumption survey;

- Industrial process losses, occurring when solvents are incorporated in surface coatings, pharmaceuticals and other products at the factory;

- Use of solvent-containing formulations in industry;

- Direct solvent use by consumers; and

- Use of solvent-containing formulations by consumers.

5.4.1   Emissions From Direct Industrial Solvent Use

Emissions in this category include those from addition of thinners to surface coatings, use of degreasing agents and cleanup solvents, and use of industrial process solvents. The uncontrolled emission factor in the EDS for this type of solvent use is 2000 lb per ton of solvent used, i.e. 100 percent.

Since the degree of emission control varies from industry to industry, we used our tape of the EDS to calculate the mean ratio between the actual TOG emission factor and the uncontrolled emission factor for all the solvent-using processes within each SIC code. For a large number of industries this ratio is 1; i.e. essentially no control is achieved.

Associated with each SIC code may be from one to several dozen processes, each of which may have its own emission factor ratio. Therefore, in order to make our emission estimates as realistic as possible, we defined the emission factor ratio for a given SIC code as the weighted average of the emission factor ratios for each of the associated processes. These ratios were weighted by the uncontrolled emissions from each process. Since the EDS reports only controlled emissions, it was necessary to find a way to base our weighting upon known information. Let T_i be the throughput for process i, and let $F_{c,i}$ and $F_{u,i}$ be the controlled and uncontrolled emission factors, respectively. Then the controlled and uncontrolled emissions are

$$E_{c,i} = T_i F_{c,i} \qquad (5.4\text{-}1)$$

$$E_{u,i} = T_i F_{u,i} \qquad (5.4\text{-}2)$$

Solving Equation 5.4-1 for T_i and substituting into Equation 5.4-2 yields an equation for the uncontrolled emissions:

$$E_{u,i} = E_{c,i} F_{u,i} / F_{c,i} \qquad (5.4\text{-}3)$$

We can now write the expression for the weighted average emission factor ratio for an SIC code j having n process:

$$R_j = \frac{E_{c,1}(F_{u,1}/F_{c,1})(F_{c,1}/F_{u,1}) + E_{c,2}(F_{u,2}/F_{c,2}) + \cdots + E_{c,n}(F_{u,n}/F_{c,n})}{E_{c,1}(F_{u,1}/F_{c,1}) + E_{c,2}(F_{u,2}/F_{c,2}) + \cdots + E_{c,n}(F_{u,n}/F_{c,n})} \qquad (5.4\text{-}4)$$

Since the ratios and their reciprocals cancel out in the numerator, we have:

$$R_j = \sum_{i=1}^{n_j} E_{c,i} \bigg/ \left[\sum_{i=1}^{n_j} E_{c,i}(F_{u,i}/F_{c,i}) \right] \qquad (5.4\text{-}5)$$

As an example, let us consider a hypothetical SIC code having two processes whose reported annual (controlled) emissions are 100 and 50 tons per year, respectively. Let the uncontrolled emission factor for each process be 2000 lb

per ton of throughput and the controlled factors be 1800 and 550 lb/ton, respectively. The emission factor ratios for the two processes are thus 0.9 and 0.275. The weighted average emission factor ratio for the SIC code is found from Equation 5.4-5:

$$R = \frac{50 + 100}{100(\frac{2000}{1800}) + 50(\frac{2000}{550})} = 0.521$$

Using the System 1022 data base management program on SAI's DEC-System 10 computer, we calculated weighted average emission factor ratios for each SIC code in our survey. For a given process within an SIC code, the data from all firms in the EDS were pooled. In many cases, R_j was equal to unity; i.e., no emission controls were used. Table 5.4-1 shows the results of our calculations for those SIC codes for which R_j was not 1. To estimate emissions from each SIC code, we then multiplied R_j times the net solvent use, as determined by our survey. Net solvent use is defined as solvent purchases minus the amounts incorporated in liquid products, sent to a recycler, and disposed of off site.

5.4.2 Emissions From Industrial Production of Solvent-Containing Formulations

This category includes process losses during the manufacture of paints, varnish, printing ink, pharmaceuticals, lube oil and grease and other solvent-containing formulations. A review of the literature was performed, paying close attention to those industrial processes included in Standard Industrial Classification (SIC) codes 28 and 29. Emission factor estimates are nonexistent for many of the industrial processes included in SICs 28 and 29 which are applicable to our market balance efforts.

Solvent lost during manufacturing of paints and varnishes (SIC 2851) averages approximately three percent (USEPA, 1976a). The emission factor for printing ink (SIC 2893) manufacture equals 120 pounds of hydrocarbons per ton of product occurring during vehicle preparation (EPA, 1976b). An emission factor for pharmaceutical manufacture (SIC 2834) was derived from data presented in AP-42 for emissions of chemicals in our market balance study. This factor equals 498 pounds of hydrocarbons per ton of solvent purchased (EPA, 1980b).

Table 5.4-1

SIC CODES HAVING WEIGHTED MEAN EF <1

SIC Code	Weighted EF Low[a]	Weighted EF Mean	High[a]	SIC Code	Weighted EF Low	Weighted EF Mean	High
2032	0.332	0.690	1.000	3479	0.857	0.888	0.919
2090	0	0.667	1.000	3494	0	0.333	0.875
2095	NA	0.130	NA	3499	0.564	0.762	0.960
2221	0.402	0.692	0.982	3511	0.454	0.684	0.914
2262	0.669	0.900	1.000	3523	0.507	0.857	1.000
2295	0.780	0.931	1.000	3531	0.902	0.968	1.000
2434	0.540	0.786	1.000	3533	0.151	0.556	0.961
2436	0.523	0.810	1.000	3537	0.779	0.909	1.000
2499	0.739	0.857	0.975	3542	0.439	0.778	1.000
2511	0.932	0.960	0.988	3545	0.125	0.667	1.000
2512	0.123	0.500	0.877	3554	0.100	0.100	0.100
2514	0.827	0.944	1.000	3569	0.031	0.400	0.769
2517	0.704	0.880	1.000	3573	0.441	0.526	0.611
2521	0.932	0.977	1.000	3599	0.867	0.932	0.997
2522	0.921	0.967	1.000	3621	0.540	0.765	0.990
2541	0.633	0.889	1.000	3631	0.736	0.918	1.000
2542	0.704	0.862	1.000	3633	0.192	0.625	1.000
2591	0.706	0.909	1.000	3634	0.619	0.846	1.000
2631	0.586	0.833	1.000	3639	0.141	0.427	0.713
2641	0.454	0.575	0.696	3643	0.507	0.857	1.000
2645	0.054	0.054	0.054	3645	0.655	0.778	0.901
2649	0.641	0.773	0.905	3651	0.786	0.900	1.000
2653	0	0.500	1.000	3662	0.605	0.700	0.795
2654	0.405	0.833	1.000	3674	0.234	0.429	0.624
2711	0.713	0.829	0.945	3675	0	0.333	0.875
2721	0.192	0.540	0.888	3679	0.869	0.894	0.919
2751	0.433	0.688	0.943	3711	0.809	0.852	0.895
2752	0	0.500	1.000	3714	0.840	0.904	0.968
2753	0.915	0.957	0.999	3721	0.712	0.790	0.868
2754	0.110	0.119	0.128	3724	0.752	0.864	0.976
2821	0.263	0.714	1.000	3728	0.897	0.942	0.987
2834	0.470	0.682	0.894	3731	0.887	0.963	1.000
2851	0.247	0.533	0.819	3732	0.911	0.970	1.000
2879	0	0.750	1.000	3743	0	0.750	1.000
2911	0.786	0.900	1.000	3751	0.465	0.850	1.000
3011	0.480	0.700	0.920	3761	0.805	0.877	0.949
3069	0.732	0.875	1.000	3769	0.184	0.288	0.392
3079	0.746	0.802	0.858	3823	0.861	0.934	1.000
3410	0.463	0.570	0.677	3825	0.290	0.563	0.836
3411	0.550	0.587	0.624	3841	0.200	0.500	0.800
3412	0.709	0.837	0.965	3842	0.139	0.389	0.639
3421	0.709	0.852	0.995	3851	0.192	0.625	1.000
3429	0.797	0.877	0.957	3861	0.625	0.796	0.967
3442	0.245	0.800	1.000	3931	0.646	0.808	0.970
3443	0.758	0.857	0.956	3949	0.820	0.914	1.000
3444	0.914	0.937	0.960	3951	0.633	0.889	1.000
3449	0.212	0.700	1.000	3964	0.597	0.838	1.000
3462	0.363	0.750	1.000	3993	0.601	0.783	0.965
3465	0	0.667	1.000	3999	0.498	0.800	1.000
3466	0.341	0.603	0.865	7211	0.583	0.793	1.000
3469	0.194	0.545	0.896	7213	0.676	0.880	1.000
3471	0.866	0.905	0.944	7216	0.936	0.946	0.956

[a] Limits of 95-percent confidence interval.

5-3

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For lube oil and grease manufacture (SIC 2992) approximately 0.03 percent of the recycled solvent is emitted (Engineering-Science, 1981).

In our market balance calculations, we used a process loss rate of 2 percent of the amount intended to be incorporated in products.

5.4.3   Emissions From Indirect Industrial Solvent Use

This category consists of emissions from industrial use of the sol-vent-containing formulations discussed in Section 6.1; they include paints, coatings, and adhesives. Since we estimated the amount of solvent used in each category, we could apply the same average emission factor ratios calculated for direct industrial solvent use. For each of the coatings categories shown in Table 6.1-4 we identified the most likely corresponding SIC codes, which are shown in Table 6.1-3.

5.4.4   Emissions From Consumer Use of Solvents

It can be argued (e.g. Taback et al., 1978) that all solvents used in consumer products eventually find their way into the atmosphere. We concurred in this assumption except in the case of ethylene glycol used in radiator anti-freeze, since it did not seem reasonable that this highly water-soluble, low-volatile compound would present an air pollution problem. A nominal emission rate of five percent was assumed.

5.5   REFERENCES

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6.0
INDIRECT SOLVENT CONSUMPTION

Solvents are present in a wide variety of formulations used in manufacturing, commercial enterprises and in the home. Use of these formulations, especially in consumer products, results in substantial solvent emissions. Since solvent contents vary in nature and magnitude from product to product, we began our analysis by defining the following product categories:

- Paints and other coatings

- Personal care products

- Household products

- Automotive products

- Industrial adhesives and sealants

- Other commercial products

Information on national use and solvent content of products in all but the last category was available. In this subsection we discuss our methodology for apportioning national values to California. Results for individual chemicals and for total solvent use are presented in Chapters 7 and 8, respectively.

6.1 PAINTS AND OTHER COATINGS

The National Paint and Coatings Association (NPCA) in Washington, DC, maintains an extensive data base on the use of solvents in coatings. SRI International (1980) recently used this data base to calculate the use of individual solvents and solvent groups by type and application of coatings. Table 6.1-1 shows the national breakdown of individual solvent use in 1979 according to the SRI study, while Table 6.1-2 summarizes the total solvent use in 1979 by application. (For ease in data presentation, Table 6.1-1 includes major coatings categories only; individual solvent use data for all subcategories were reported by SRI and used by SAI in the following method.)

To estimate California solvent use it was necessary first to adjust the national values to account for changes in use between 1979 and 1980, and

Table 6.1-1

NATIONAL USE OF INDIVIDUAL SOLVENTS IN PAINTS
AND COATINGS, 1979
(All uses in millions of pounds)

Solvent Type	Product Finishes-OEM	Architec-tural	Special Purpose	Thinners Misc.	Total
Aliphatic hydrocarbons	345.3	436.0	162.8	150.9	1,095.0
Toluene	233.5	0.1	79.3	262.1	575.0
Xylenes	251.2	4.3	92.8	146.7	495.0
Other aromatics	78.6	-	36.6	74.8	190.0
n-Butyl alcohol	101.3	-	4.5	4.2	110.0
Ethyl alcohol	43.4	0.4	6.2	150.0	200.0
Isopropyl alcohol	56.0	-	7.7	63.3	127.0
Other alcohols	35.4	3.0	13.4	43.2	95.0
Acetone	49.6	-	9.7	130.7	190.0
Methyl ethyl ketone	129.4	-	35.3	202.3	367.0
Methyl isobutyl ketone	94.0	-	11.0	7.0	112.0
Ethyl acetate	31.5	-	33.8	46.7	112.0
Butyl acetate	48.7	-	31.6	17.7	98.0
Propyl acetate	24.7	-	17.3	11.0	53.0
Other ketones and esters	41.5	0.7	· 17.3	49.5	109.0
Ethylene glycol	4.3	57.0	0.1	-	61.4
Propylene glycol	0.2	38.1	-	-	38.3
Other glycols	-	1.2	-	-	1.2
Glycol ethers and ether esters	104.9	35.9	23.8	60.4	225.0
Methylene chloride	-	-	13.4	3.6	17.0
Others	29.0	-	5.0	7.0	41.0

Source: SRI, 1980.

Table 6.1-2

TOTAL NATIONAL SOLVENT USE IN PAINTS AND
COATINGS, BY TYPE OF APPLICATION, 1979

(All quantities in millions of pounds)

Coating Category	Subcategory Use	Major Category Total	Subcategory Percent	Major Category Percent
PRODUCT FINISHES - OEM				
Wood Furniture & Fixtures	316.2		7.3	
Wood Flat Stock	116.4		2.7	
Metal Furniture &				
Fixtures	117.3		2.7	
Containers & Closures	187.4		4.3	
Sheet, Strip, & Coil	112.7		2.6	
Major Appliances	46.3		1.1	
Other Appliances	31.4		0.7	
Automotive				
Topcoat	93.1		2.2	
Primer	46.0		1.1	
Underbody Components & Parts	41.2		1.0	
Trucks & Buses	41.5		1.0	
Railroad	16.8		0.4	
Aircraft	15.7		0.4	
Machinery & Equipment	161.4		3.7	
Electrical Insulation	76.8		1.8	
Marine				
Pleasure	4.4		0.1	
Commercial & Maintenance	57.6		1.3	
Paper, Film & Foil	40.2		0.9	
Other Product Finishes	180.1		4.2	
Product-OEM Total		1,702.5		39.5
ARCHITECTURAL				
Interior Water-based				
Flat	29.2		0.7	
Semi-gloss & Gloss	51.9		1.2	
Other	3.5		0.1	
Interior Solvent-based				
Flat	46.8		1.1	
Semi-gloss & Gloss	73.5		1.7	
Varnish	16.1		0.4	
Other	39.9		0.9	

Table 6.1-2

TOTAL NATIONAL SOLVENT USE IN PAINTS AND
COATINGS, BY TYPE OF APPLICATION, 1979
(Continued)
(All quantities in millions of pounds)

Coating Category	Subcategory Use	Major Category Total	Subcategory Percent	Major Category Percent
Exterior Water-based				
Flat (House Paints)	38.4		0.9	
Trim	3.6		0.1	
Stains	3.0		0.1	
Other	4.1		0.1	
Exterior Solvent-based				
Flat (House Paints)	82.7		1.9	
Enamel	62.3		1.4	
Primer	25.8		0.6	
Varnish	14.4		0.3	
Stains	68.1		1.6	
Other	13.4		0.3	
Architectural Total		576.7		13.4
SPECIAL PURPOSE COATINGS				
Maintenance	118.8		2.8	
Auto Refinishing	192.4		4.5	
Other Refinishing	42.7		1.0	
Traffic Paints	147.9		3.4	
Other	99.8		2.3	
Special Purpose Total		601.6		14.0
Thinner & Miscellaneous		1,431.0		33.2
PAINTS & COATINGS TOTAL		4,311.8		100.0[a]

Source: SRI, 1980.

[a] Sum of subcategory percentages equals 100.1 due to rounding error.

then to apportion the 1980 figures from national to California use rates. The general formula for this apportionment was:

$$U_{C,i,j,80} = U_{N,i,j,79} \left(\frac{A_{N,j,80}}{A_{N,j,79}} \right) \left(\frac{A_{C,j,B}}{A_{N,j,B}} \right) \tag{6.1-1}$$

where

$U_{C,i,j,80}$ = California use of solvent i in coatings category j in 1980,

$U_{N,i,j,79}$ = National use of solvent i in coatings category j in 1979,

$A_{N,j,79}$ and $A_{N,j,80}$ = National value of adjustment parameter for coatings category j in 1979 and 1980, respectively,

$A_{N,j,B}$ = National value of adjustment parameter for coatings category j in a base year, and

$A_{C,j,B}$ = California value of adjustment parameter for coatings category j in the same base year

The adjustment parameters are measures of activity levels which could reasonably be expected to influence solvent use in a particular category. As will be seen below, they include production worker hours, number of homes, population, and other measures. One can restate Equation 6.1-1 as:

$$U_{C,i,j,80} = U_{N,i,j,79} \, P_j \tag{6.1-2}$$

where

$$P_j = \left(\frac{A_{N,j,80}}{A_{N,j,79}} \right) \left(\frac{A_{C,j,B}}{A_{N,j,B}} \right) \tag{6.1-3}$$

With three exceptions, we assume that a single proportionation factor, P_j, applies to all the solvents used in a given coatings category. This assumption may not be valid in the case of architectural coatings, since state and local district regulations have in recent years tended to favor the use of water-based coatings, whose solvent speciation differs from that of oil-based coatings. Solvent-specific proportionation factors were calculated for maintenance coatings, other special purpose coatings, and thinners. The rationale for their calculation is discussed below.

Table 6.1-3 shows the adjustment factors and base years used to calculate the proportionation factor for each coatings category. (Coatings category numbers are defined in Table 6.1-4.) The first step was to identify the industries in which each type of coating is most likely to be used. Most Standard Industrial Classification (SIC) codes were provided in the SRI report; where they were missing, we chose those which were, in our judgment, most appropriate. The base year (corresponding to the subscript B in Equations 6.1-1 and 6.1-3) was the latest for which relevant data were available for both California and the U.S. In most cases this was 1977, since that was the last year for which California-specific data were published by the Census Bureau (U.S. Census Bureau, 1980b).

Some aggregation of the NPCA coatings categories was necessary. For example, the Census of Manufactures does not report production worker hours for California for the appliance industry. We therefore used the three-digit SIC code 363 (household appliances) to cover the NPCA categories "major appliances" and "other appliances." (See Table 6.1-2.) Interior use of architectural coatings was assumed to be proportional to the number of households, including owner-occupied and rental units. The number of households was, in turn, assumed to be proportional to population. The category "other refinishing," includes refinishing of machinery, equipment, and other hardware. No SIC code can be readily identified with this use of coatings. We assumed that the quantity of coatings used in refinishing was proportional to that used in original machinery and equipment manufacture.

Three coatings categories required special treatment. We assumed that California use of solvents in maintenance coatings bore the same ratio to total California use in original equipment manufacture (OEM) as national use in maintenance coatings had to national OEM use in 1979. OEM uses include coatings categories 1 through 15, which are described in Table 6.1-4. Rearranging the terms of this pair of ratios, we see that:

$$U_{C,i,21} = \left(\sum_{j=1}^{15} U_{C,i,j} \right) (U_{n,i,21}) / \left(\sum_{j=1}^{15} U_{N,i,j} \right) \qquad (6.1\text{-}4)$$

Table 6.1-3

DATA USED TO CALCULATE PROPORTIONATION FACTORS
FOR CALIFORNIA SOLVENT USE IN COATINGS

Coatings Category[a] j	Standard Industrial Classification Codes	Adjustment Parameter	$A_{N,j,79}$	$A_{N,j,80}$	Base Year	$A_{C,j,B}$	$A_{N,j,B}$	Ref.[b]
1	2511,2512,2517 2521,2541	MPWH[c]	483.8	456.1	1977	46.05	447.5	1,2
2	2451, 2452, 2492	MPWH	127.8	100.9	1977	15.9	132.0	1,2
3	2514, 2522, 2542	MPWH	145.8	138.7	1977	16.8	135.7	1,2
4	3411, 3412	MPWH	123.6	114.5	1977	18.3	126.5	1,2
5	3479	MPWH	61.4	60.9	1977	5.8	52.2	1,2
6	363[d]	MPWH	229.2	227.0	1977	7.3	243.2	1,2
7	—	1000 Autos produced	8,434	6,376	1980	261.2	6,376	3
8	3713	MPWH	54.9	54.8	1977	4.4	54.8	1,2
9	3743	MPWH	108.4	90.4	1977	0.6	79.4	1,2
10	3721,3724,3728	MPWH	674.3	653.3	1977	98.3	475	1,2
11	352, 353, 354, 355, 356, 357, 3581, 3585, 3586	MPWH	2,551.8	2,444.0	1977	154.12	2,223.8	1,2
12	3612, 3613, 3621	MPWH	334.4	299.3	1977	15.4	307.3	1,2
13	3731, 3732	MPWH	340.1	343.6	1977	35.4	345.6	1,2

Table 6.1-3 (Continued)

DATA USED TO CALCULATE PROPORTIONATION FACTORS
FOR CALIFORNIA SOLVENT USE IN COATINGS

Coatings Category[a] j	Standard Industrial Classification Codes	Adjustment Parameter	$A_{N,j,79}$	$A_{N,j,80}$	Base Year	$A_{C,j,B}$	$A_{N,j,B}$	Ref.[b]
14	3479	MPWH	61.4	60.9	1977	5.8	52.2	1,2
15	3479	MPWH	61.4	60.9	1977	5.8	52.2	1,2
16	-	1000 single-family homes	57,005	58,290	1980	5,725	58,290	4
17	-	1000 persons	224,567	e	1980	23,669	e	2
18	-	1000 autos registered	120,248	121,724	1980	13,268	121,724	3
19	Same as 11	MPWH	2551.8	2,444.0	1977	154.12	2,223.8	1,2
20	-	1000 miles	3,918.8	3,955.4	1980	-180.7	3,955.4	5

[a] See Table 6.1-4 for definitions of coatings categories.

[b] References: 1-US Census Bureau, 1977; 2-US Census Bureau, 1980b; 3-Motor Vehicles Manufacturing Association, 1982; 4-US Department of Housing and Urban Development, 1982; 5-US Federal Highway Administration, 1982.

[c] MPWH = Million production worker hours.

[d] In order to maintain confidentiality, the Census Bureau reports data at the three-digit SIC level only.

[e] In this case the adjustment factors $A_{N,17,80}$ and $A_{N,17,B}$ are equal and therefore cancel out. (See Equation 6.1-1).

Table 6.1-4

FACTORS USED TO PROPORTIONATE 1979 NATIONAL SOLVENT USE IN COATINGS TO 1980 CALIFORNIA USE

Category Number j	Coatings Category	Proportionation Factor P_j
1	Wood furniture and fixtures	0.09701
2	Wood flat stock	0.09510
3	Metal furniture and fixtures	0.1178
4	Containers and closures	0.1340
5	Sheet, strip and coil	0.1102
6	Appliances	0.02973
7	Automotive	0.03098
8	Trucks and buses	0.08160
9	Railroad	0.00630
10	Aircraft	0.2005
11	Machinery and equipment	0.06640
12	Electrical insulation	0.04485
13	Marine	0.1035
14	Paper, film and foil	0.1102
15	Other product finishes	0.1102
16	Architectural/interior	0.1054
17	Architectural/exterior	0.1004
18	Auto refinishing	0.1103
19	Other refinishing	0.06640
20	Traffic paints	0.04612
21	Maintenance	a
22	Other special purpose	a
23	Thinners and miscellaneous	a

a Varies with solvent type. See text.

California use of "other special purpose" coatings was assumed to bear the same ratio to total California special purpose coatings (categories 18 through 22) as national other special purpose coatings bore to national total special purpose coatings. We can express this relationship as follows:

$$\frac{U_{C,i,22}}{\left(\sum_{j=18}^{21} U_{C,i,j}\right) + U_{C,i,22}} = \frac{U_{N,i,22}}{\sum_{j=18}^{22} U_{N,i,j}} \tag{6.1-5}$$

Solving Equation 6.1-5 for $U_{C,i,22}$ we obtain:

$$U_{C,i,22} = \frac{(U_{N,i,22}) \sum_{j=18}^{21} U_{C,i,j}}{\left(\sum_{j=18}^{22} U_{N,i,j}\right) - U_{N,i,22}} \tag{6.1-6}$$

Similarly, the ratio of California use of solvents in the "thinners and miscellaneous" category to the total solvent use for coatings in California was assumed to equal the corresponding national ratio. The value for $U_{C,i,23}$ was therefore:

$$U_{C,i,23} = \frac{(U_{N,i,23}) \sum_{j=18}^{22} U_{C,i,j}}{\left(\sum_{j=1}^{22} U_{N,i,j}\right) - U_{N,i,23}} \tag{6.1-7}$$

Note that in these last three categories, the proportionation factor P will be different for each solvent species.

Table 6.1-4 lists the proportionation factors used by SAI. Note that the common rule-of-thumb that California accounts for about 10 percent of the use of various industrial and consumer products applies for several coatings categories, but by no means all. Given the state's large aircraft and

aerospace industry, it is not surprising that P_{10} is about 0.20. Appliances, automobile manufacturing, and several other coatings categories account for considerably less than 10 percent of the national total solvent use.

Finally, Table 6.1-5 shows the estimated total California use of solvents in paints and coatings for each coating subcategory. This use consists of 262 million lbs (131,000 tons) included in the coatings and 130 million lbs (65,000 tons) as thinners, for a total of 392 million lbs (196,000 tons). The proportionation factors in Table 6.1-4 were also used to estimate use of individual solvent species. Results of the calculation for each chemical are presented in Chapter 7.

6.2   PERSONAL CARE PRODUCTS

The principal personal care products found by our literature review to have significant solvent contents were:

- Nail care items (including polish remover)
- Shaving cream
- Deodorants
- After shave lotions
- Pre-shave lotions

Perfume sticks and electric shaver cleaners may contain propylene glycol (Gosselin, 1976). However, no data on perfume stick use could be found, and a market research study by Simmons Market Research Bureau (1980) indicated that shaver cleaner use is negligible. Similarly, methylene chloride is an ingredient of one brand of men's hair spray, but its use is insignificant. Our procedure for estimating solvent emissions from each of these categories was as follows.

6.2.1   Nail Care

As with many consumer products, formulation information other than that stated on labels is not readily available. Some data for specific pro-

Table 6.1-5

TOTAL CALIFORNIA SOLVENT USE IN PAINTS AND
COATINGS, BY TYPE OF APPLICATION, 1980
(All quantities in millions of pounds)

Coating Category	Subcategory Use	Major Category Total	Subcategory Percent	Major Category Percent
Product Finishes - OEM				
Wood Furniture and Fixtures	30.676		7.84	
Wood Flat Stock	11.070		2.83	
Metal Furniture and Fixtures	13.815		3.53	
Containers and Closures	25.114		6.42	
Sheet, Strip and Coil	12.420		3.17	
Appliances	2.310		0.59	
Automotive	5.585		1.43	
Trucks and Buses	3.346		0.85	
Railroad	0.106		0.03	
Aircraft	3.148		0.80	
Machinery and Equipment	10.716		2.74	
Electrical Insulation	3.445		0.88	
Marine	6.416		1.64	
Paper, Film and Foil	4.430		1.13	
Other Product Finishes	19.848		5.07	
Product-OEM Total		152.445		38.95
Architectural				
Interior	27.498		7.03	
Exterior	31.716		8.11	
Architectural Total		59.214		15.14
Special Purpose				
Auto Refinishing	21.229		5.42	
Other Refinishing	2.835		0.72	
Traffic Paints	6.821		1.74	
Maintenance	10.675		2.73	
Other	8.397		2.15	
Special Purpose Total		49.957		12.76
Thinners		129.688		33.14
Grand Total		391.304		100.0

ducts and two general formulations are presented in Gosselin (1976). The Cosmetic, Fragrance and Toiletry Association was contacted for additional information (Kimball, 1982). Table 6.2-1 shows the solvent content of major nail polish types, as determined by SAI. Virtually all types of nail coatings contain butyl acetate, toluene and ethyl acetate. While xylene is present in some brands of polish, it is absent from most popular brands (e.g. Revlon[TM], Sally Hansen[TM] and Cover Girl[TM]).

According to a survey performed by the Simmons Market Research Bureau (1980), 63.7 percent of adult females either apply nail polish themselves at home or have their nails done at salons; since there are 8.440×10^6 adult females in California (Mielke, 1982), 5.376×10^6 meet this description. Since nail care product use patterns are different for home use and at salons, it was necessary to estimate how many women fall into each category. In a survey conducted by Modern Salon (1982), 81 percent of the women interviewed said that they did their own nails, 9 percent had them done at salons only, and 10 percent did them at home and at salons. We assume that these percentages apply to adult females in general (i.e. not just to those who have their hair done at salons). The number of women in each category is therefore:

Home only = 5.376×10^6 (81)/(81 + 10) = 4.785×10^6
Home or salon = 5.376×10^6 (10)/(81 + 10) = 5.91×10^5
Salon only = 5.91×10^5 (9/10) = 5.32×10^5

In addition the Simmons Market Research Bureau study showed that one quarter of the California females in the 15-19 year-old population, or 2.596×10^5 persons, do their own nails at home.

The number of bottles of each coating type consumed by each type of user was determined as the number of users x frequency of nail care x frequency of use of coating type x fraction of a bottle per use. Frequency of nail care was determined by the Simmons Market Research Bureau survey, discussions with salons, and an informal survey of SAI staff. It was assumed that clear enamel is used 25 percent of the time, and only in salons. The service limit of a typical bottle was assumed to be 20 applications. Table 6.2-2 shows the results of our consumption estimates.

Table 6.2-1

ORGANIC SOLVENT CONTENT OF MAJOR BRANDS OF NAIL POLISH
(Percent by weight)

Type	Butyl Acetate	Ethyl Acetate	Toluene	Xylene
General polish	17.8 - 31.4	13.1 - 28.4	2.5 - 26.8	0 - 8.7
General top coat	21.3	14.6	30.6	10.1
Avon Clear Nail[tm]	19.7	13.2	27.2	8.7
Avon base coat	17.7	30	28	-
Cutex polish	25 - 50	10 - 25	10 - 25	-
Nail lacquer	15	35	20	-
Other brands[a]	20	25	20	-

Source: Gosselin (1976) and Cosmetic, Fragrance and Toiletry Association (Kimball, 1982).

[a] SAI estimate.

Table 6.2-2

CALCULATION OF BOTTLES OF NAIL CARE PRODUCTS CONSUMED
IN CALIFORNIA

Location of Use	1000 Persons	Frequency (times/yr)	1000 Bottles Consumed			
			Nail Enamel	Clear Enamel	Base Coat	Top Coat
Home only (adults)	4,785	43.2	10,335.6	-	-	
Home only (15-19)	260	18	233.6	-		
Salons only	532	36	718.2 =	119.7	478.8	119.7
Home and salons	591	12	266.0 =	44.3	177.3	44.3
Total Consumption			11,553.4	164.0	656.1	164.0

The density of all nail polishes was assumed to be approximately 1 g/cm^3. Since the average bottle is 0.5 oz, the average weight per bottle is 0.033 lb. Using this information, as well as the solvent composition data presented in Table 6.2-1, we estimated total use of solvent in nail polishes in California in 1980 to be 272,000 lb (136 tons). Consumption of individual solvents is discussed in Chapter 7.

Finally, we considered use of acetone in nail polish remover. The solvent content of these products is roughly 50 percent (Gosselin, 1976). From a random sample of SAI staff, we estimate that about 0.1 oz of remover is used for every application of nail coating. Given the application frequencies listed in Table 6.2-2 we estimate that there were 2.4 x 10^8 applications of nail coatings in California. Assuming a polish remover density of 1 g/cm^3 (8.345 lb/gal), we estimate an acetone use of 800,000 lb (400 tons).

6.2.2   Shaving Cream

The only major solvent of interest in shaving cream is propylene glycol, which, according to Gosselin (1976), is present at between 0 and 15 percent by weight; we used 5 percent in our calculations. The only brand containing propylene glycol is Colgate "Instant Shave," which is preferred by 18.5 percent of the men and 31.0 percent of the women who use any shaving cream (Simmons Market Research Bureau, 1980). According to the cited study, 60.8 percent of males and 17.9 percent of females use shaving cream, and the use frequencies are 273 and 101 uses per year, respectively. According to the Gillette Medical Evaluation Laboratory (Wernick, 1982) the average weight per use of shaving cream is 5 g. Using this information, along with the California male and female populations, we estimated propylene glycol use to be 140,000 lb (70 tons) per year.

6.2.3   Deodorant

Stick deodorants contain 4 to 5 percent propylene glycol by weight, while aerosol products contain an average of 1.5 percent, according to an in-

dustry source. None of the roll-on deodorants or antiperspirants on the market contain solvents of interest. According to the Simmons Market Research Bureau (1980), 87.4 percent of males and 92 percent of females use deodorants, and their use rates are 400.9 and 427.7 times per year per person, respectively. As seen in Table 6.2-3, approximately 140,000 lb/yr (70 tons/yr) of propylene glycol is used in deodorants in California.

6.2.4   After Shave and Electric Pre-Shave Lotion

After shave products consist mainly of denatured alcohol and propylene glycol. In our analysis, we assumed that the denatured alcohol was essentially ethanol. Three brands of after shave lotion, accounting for 44.5 percent of the market, contain propylene glycol (Simmons Market Research Bureau, 1980). According to a representative of the Cosmetic, Fragrance and Toiletry Association (Kimball, 1982), one can get an average of 35 uses per ounce. Other market data show that 72.4 percent of the adult male population uses after shave lotion, and that the use frequency is 312 times per year. Using this information, we estimate that ethanol and propylene glycol use in these products are 2.7 million lbs/yr (1,340 tons/yr) and 30,500 lb/yr (15.3 tons/yr), respectively.

Only one brand of electric pre-shave lotion, accounting for 12.5 percent of the market, contains propylene glycol. Using other market research information, we estimated that ethanol and propylene glycol use are 340,000 lb (170 tons) and 1,100 lb (0.5 tons) per year, respectively.

6.2.5   Rubbing Alcohol

The main constituent of rubbing alcohol is isopropanol, which is normally present at 70 percent by volume. National sales of rubbing alcohol in 1980 were $37,697,000 (Anon., 1981a). We assume that California sales were in proportion to the state's share of U.S. households, or 10.762 percent (Anon., 1981b). From an SAI survey of rubbing alcohol prices on drugstore shelves, we assume an average price of $1 per pint bottle. Given the density of isopropanol, we estimate total use (and consequent evaporation) in California of 2.3 million lb (1,150 tons).

Table 6.2-3

CALCULATION OF PROPYLENE GLYCOL USE IN DEODORANTS

Population Category	Product Type	Total Users of Deodorants	Product User Fraction[a]	Product Uses[b]	Pounds per Use[c]	Solvent Fraction	Solvent Use (lb/yr)
Males	Stick	7.13×10^6	0.441	1.26×10^9	1.9×10^{-3}	0.045	1.1×10^5
Males	Aerosol	7.13×10^6	0.101	2.89×10^8	2.4×10^{-3}	0.015	1.0×10^4
Females	Stick	7.96×10^6	0.0413	1.41×10^8	1.9×10^{-3}	0.045	1.2×10^4
Females	Aerosol	7.96×10^6	0.0942	3.21×10^8	2.4×10^{-3}	0.015	1.2×10^4
Totals				2.01×10^9			1.4×10^5

[a] Based on market share of those brands containing propylene glycol (Simmons Market Research Bureau, 1980).

[b] Based upon 400.9 and 427.7 uses per year by males and females, respectively (Simmons Market Research Bureau, 1980).

[c] Based on discussions with a major producer.

6.3   HOUSEHOLD PRODUCTS

6.3.1   General Purpose Cleaners

The Simmons Market Research Bureau (1980) study showed that 89.2 percent of households use general purpose cleaning products.   Another survey (Anon., 1981b) estimated that there were 8.814 million households in California in 1980.   Review of other market data showed that the average household buys 3.4 packages of cleaning products.   Three major brands of cleaners, accounting for 33.8 percent of the market, use ethylene glycol monobutyl ether.   Average weight percentages of solvents were found in Gosselin (1976). Since packages of each brand come in more than one size, SAI staff examined supermarket stock to determine the average weight per package sold.   Since these products are at least 90 percent water, it was assumed that the total product density was 8.345 lb/gal.   Table 6.3-1 shows how the California solvent use was determined for each brand.   Total use of ethylene glycol monobutyl ether in household cleaners is estimated to be 700,000 lb (350 tons) per year.

6.3.2   Window Cleaners

Ethylene glycol monoethyl ether is the main solvent of interest in window cleaners, which are used in 84.4 percent of households.   Isopropyl alcohol is used in one brand.   As in the case of general purpose cleaners, we surveyed supermarket store shelves to determine average weights per package for major brands.   Other data were obtained from the Simmons Market Research Bureau (1980) and Gosselin (1976).   Again, total product density was assumed to be 8.345 lb/gal.   Table 6.3-2 shows how the California solvent use was determined for each brand.   Total use of ethylene glycol monoethyl ether and isopropyl alcohol in window cleaners are estimated to be 1.2 million lb (600 tons) and 420,000 lb (210 tons) per year, respectively.

6.3.3   Spot Removers

Solvents in spot removers consist mainly of petroleum solvents, aromatic hydrocarbons and chlorinated hydrocarbons.   Composition data for common

Table 6.3-1

ESTIMATION OF ETHYLENE GLYCOL MONOBUTYL ETHER USE
IN GENERAL PURPOSE HOUSEHOLD CLEANERS

Brand	Market Share	Packages Sold	Ave. Wt. per Package (lb)[a]	EGMBE Fraction	EGMBE Used (lb)
Dow	0.0885	2.27×10^6	1.3	0.06	1.8×10^5
Fantastik	0.1464	3.91×10^6	1.8	0.045	3.2×10^5
Formula 409	0.1064	2.84×10^6	2.0	0.035	2.0×10^5
Totals		9.02×10^6			7.0×10^5

[a] Determined from SAI survey of market shelves

Table 6.3-2

ESTIMATION OF ETHYLENE GLYCOL MONOETHYL ETHER USE
IN WINDOW CLEANERS

Brand	Market Share	Containers Sold	Ave. Wt. per Container (lb)[a]	EGMEE Fraction	EGMEE Used (lb)
Ajax	0.069	1.63×10^6	1.0	0.03	4.9×10^4
Glass Plus	0.253	5.98×10^6	3.1	0.025	4.6×10^5
Windex	0.597	1.41×10^7	1.0	0.05[b]	7.0×10^5
Totals		2.17×10^7			1.2×10^6

[a] Determined from SAI survey of market shelves

[b] Ethylene glycol monoethyl ether and isopropanol assumed to share equally the 10-percent solvent content reported by Gosselin (1976).

brands were obtained from Gosselin (1976) and from product labels; those for three major brands are shown in Table 6.3-3. According to a study by Super-market Business staff (Anon., 1981c), the 1980 U.S. retail market for spot re-movers was $30,450,000. California accounted for 11.2 percent of national re-tail sales; assuming that this proportion applies to spot removers, the amount spent on this product in the state would be $3,410,400. SAI staff surveyed the shelves of two major supermarkets and drugstores to determine the average unit price for each brand. These prices, along with the market fraction of each brand, are shown in Table 6.3-4. The number of units of each brand sold in California was estimated in the following manner.

Let B_i be the number of units of brand i sold in California and let P_i be the corresponding unit price. Then $B_i P_i$ = $3,410,400. If the sub-scripts 1 through 4 correspond to K2R^{TM} aerosol, K2R^{TM} paste, Carbona^{TM} liquid and the combination of Energine^{TM} and Renuzit^{TM}, respectively, then the follow-ing relationships may be seen from the market share information presented in Table 6.3-4:

$$B_2 = 10B_1$$

$$B_3 = \frac{0.123}{0.5482} \, B_1 = 0.2244 \, B_1$$

$$B_4 = \frac{0.274}{0.5482} \, B_1 = 0.4993 \, B_1$$

Using the unit price information, we can set up and solve the following equa-tion for B_1:

$$B_1 \, (1.79) + 0.10B_1 \, (1.19) + 0.2244B_1 \, (1.39) + 0.4998 \, (1.39) = 3,410,400$$

$$B_1 = 1,169,692 \text{ units sold}$$

The number of units of the other brands, along with the weights of each unit, are shown in Table 6.3-4. Carbona^{TM} liquid was assumed to have a specific gravity of 0.8. For the three brands whose solvent composition was known, the

Table 6.3-3

SOLVENT CONTENT OF MAJOR BRANDS OF SPOT REMOVERS
(Percent by weight)

Brand	Aliphatic Hydrocarbon	Methyl Chloroform	Methylene Chloride	Perchloro-ethylene	Toluene	Trichloro-ethylene	Xylene
Carbona Liquid[a]	50	10	--	--	--	40	--
K2R Aerosol	--	25	15	16	--	--	--
K2R Paste	10	16	27	17	15	--	15

a Assumed to have same composition as Carbona aerosol, which was not found on the shelves in SAI's supermarket survey

Table 6.3-4

MARKET SHARE OF MAJOR BRANDS OF SPOT REMOVERS

Brand	Market Fraction	Unit Price[b] ($)	Unit Weight (oz)	Estimated Units sold in California
K2R Aerosol	0.5482	1.79	6	1.2×10^6
K2R Paste	0.0548[c]	1.19	0.8	1.2×10^5
Carbona Liquid	0.123	1.39	4	2.6×10^5
Energine	0.274	1.39	4	5.8×10^5
Renuzit				
Totals	1.000			2.2×10^6

a Simmons Market Research Bureau (1980).

b SAI survey of supermarkets and drug stores.

c The market fraction for aerosol and paste combined was 0.603; we observed that the paste appeared on the shelves with one-tenth the frequency of the aerosol.

use of each solvent was calculated as the product of the units sold, the unit weight and the solvent fraction. For example, methyl chloroform use in K2R^{TM} paste is estimated to be (116,969 units)(0.8 oz/unit)(1b/16 oz)(0.16) = 936 lb. Since no composition data were available for two of the brands, the total for the state was computed by multiplying solvent use for the three known brands by the reciprocal of their combined market share. We thus estimate that spot remover use in California results in use of 38,500 lb (19.3 tons) of aliphatic hydrocarbons, 160,000 lb (80 tons) of methyl chloroform (1,1,1-trichloroethane), 93,000 lb (46.5 tons) of methylene chloride, 98,000 lb (49 tons) of perchloroethylene, 1,200 lb (0.6 tons) of toluene, 30,000 lb (15 tons) of trichloroethylene, and 1,200 lb (0.6 tons) of xylene; total solvent use is 421,900 lb (211 tons).

6.3.4   Ball Point and Porous Tip Pens

Information on the amount of ink in, and the solvent composition of, fine line porous tip, other porous tip (except marking), rolling point and broad tip marking pens was obtained from the Federal Bureau of Alcohol, Tobacco and Firearms (Cantu, 1982) and from two major pen manufacturers (Kuranz, 1982; Anon, 1982a). Inks used in ballpoint pens (including disposable pens and refills) must have high viscosity and thus contain high-molecular-weight glycols and glycol ethers. Since the air pollution potential of these inks is negligible, they were not included in our estimations. The principal solvent in the remaining types of pens used by consumers is ethylene glycol, although glycol ethers are used in some pens with water-based inks.

Sales data were obtained from two market surveys (Anon., 1982a; Anon., 1981c). Although these surveys contained much valuable data, no information was available for fountain pen ink sales. Also, it is uncertain whether commercial use of pens (e.g. large-lot purchases by offices) is included. Thus our estimates will probably be lower than the actual values.

Table 6.3-5 summarizes the information obtained for the four main types of pen. Average prices were determined by an SAI survey of two supermarkets, two drug stores and one office supply store. California sales were assumed to be 11.2 percent of national sales. Ethylene glycol use in pens is estimated to be 37,000 lb/yr (18 tons/yr).

Table 6.3-5

ESTIMATION OF ETHYLENE GLYCOL USE IN PENS

Type of Pen	Estimated California Sales ($)	Average Retail Price ($)	Units Sold in California	Wt. of Ink in Pen (g)	Solvent Fraction	Solvent Used (lb)
Fine line porous tip	2.10×10^7	0.89	2.36×10^7	1.5	0.175	1.4×10^4
Other porous tip	9.07×10^6	0.89	1.02×10^7	2	0.175	7.9×10^3
Rolling point	1.42×10^7	0.79	1.80×10^7	1.5	0.175	1.0×10^4
Broad tip marker	6.27×10^6	0.76	8.25×10^6	5	0.06	5.5×10^3
Totals	5.05×10^7		6.01×10^7			3.7×10^4

6.3.5   Household Adhesives Use

Results of an adhesives sales survey undertaken by a trade association were provided to SAI with the condition that the source not be identified. The survey did not include all adhesives producers in the country and would therefore be expected to underpredict total sales. According to the survey, 27.7 million lb of solvent-based adhesives and 22.1 million lb of solvent-based sealants were used by households in 1981. (Data for 1980 were unavailable.) If we assume that California use is proportional to population, then 10.1 percent of these amounts were used in the state. Table 6.3-6 shows the solvent content of various domestically-used adhesives, according to Gosselin (1976). Unfortunately data on neither the relative use of the different adhesives types nor the solvent composition of sealants were available. From the composition data shown in Table 6.3-6, we estimate use of 370,000 lb (185 tons) of acetone, 12,000 lb (6 tons) of butyl acetate, 63,000 lb (31.5 tons) of ethyl acetate, 600,000 lbs (300 tons) of hexane and 380,000 lb (190 tons) of toluene, for a total solvent use of 1.4 million lb (710 tons) of solvents in domestic adhesives. The use of solvents in sealants will not be estimated, but is probably of the same order of magnitude.

6.4   AUTOMOTIVE PRODUCTS

The most important solvent-containing automotive products are radiator antifreeze, windshield washer and gasoline line antifreeze, and brake fluid. Other products are shown in Gosselin (1976) as containing solvents of interest to this study. However, perusal of product labels showed that these solvents are no longer widely used.

6.4.1   Radiator Antifreeze

Cooling system antifreeze products are based on ethylene glycol, which both depresses freezing points and elevates boiling points. Antifreezes used today are changed as needed, rather than at the end of the winter season. Ernst and Whinney (1981) surveyed 11 ethylene glycol-based antifreeze manufacturers for the Chemical Specialties Manufacturers Association. National sales to civilian and government consumers in 1980 were 184.3 million gallons. No breakdown by vehicle type was reported.

Table 6.3-6

SOLVENTS CONTAINED BY COMMON TYPES OF ADHESIVES
(Values are percent by weight)

Adhesive Type	Acetone	Butyl Acetate	Ethyl Acetate	Hexane	Toluene
Nitrocellulose cement	39	-	-	-	-
China cement[a]	20 - 40	0 - 5	UA[b]	UA	20 - 30
Rubber cement	UA	-	-	90	UA
Leather glue	-	-	5	25	45
Metal cement	15 - 25[c]	-	-	-	-
Model cement	30 - 85	d	20 - 25	30	20 - 25

Source: Gosselin, 1976

[a] Also contains methyl ethyl ketone, butanol, and methyl isobutyl ketone.

[b] UA = unspecified amount.

[c] May contain other ketones.

[d] Butyl acetate sometimes used.

According to the Motor Vehicle Manufacturers Association (Anon., 1982b), total U.S. vehicle registration in 1980 was 154.3 million vehicles. California registration at the end of that year was 15.0 million vehicles. Assuming that California's antifreeze use is proportional to its fraction of vehicle registration, we estimate statewide antifreeze use to be 17.9 million gallons. Since the major brands of antifreeze contain at least 95 percent ethylene glycol, we assume that the density of the solution is 9.25 lb/gal, so that 165 million lb (83,000 tons) of ethylene glycol was used in California in 1980.

6.4.2   Windshield Washer Antifreeze and Gasoline Drier

Windshield washer antifreeze is sold as a premix or as a concentrate. Typical volumetric percentages for these formulations are 35 and 68 percent, respectively (Gosselin, 1976). Sales data for 1980 were unavailable. According to a survey by Charles H. Kline and Company, Inc. (1975), 1974 U.S. sales of premix and concentrate were 14 and 2 million gallons, respectively. According to the Motor Vehicle Manufacturers Association (Anon., 1982b), U.S. vehicle registration grew by 20.45 percent between 1974 and 1980. Using that growth factor and the California percentage of vehicle registration (mentioned above), we estimate that 1.64 million gallons of premix and 234,000 gallons of concentrate were sold in California in 1980.

Methanol is the principal solvent in these products. The densities of methanol solutions at the stated concentrations are 7.75 lb/gal for premix and 7.19 lb/gal for concentrate. Use of methanol in these products in 1980 is therefore estimated to be 13 million lb (6,500 tons) and 1.7 million lb (850 tons), respectively, for a total of 14.7 million lb (7,350 tons).

Gasoline drier contains about 97 percent methanol. U.S. sales of this product in 1974 were 1.5 million gallons (Charles H. Kline and Company, 1975). Using the same proportionation method as was used for antifreeze, we estimate California sales of 176,000 gal in 1980. The density of a 97-percent methanol solution in water is 6.69 lb/gal. Our estimate of methanol use in this product is therefore 1.2 million lb (600 tons).

6.4.3   Brake Fluid

Brake fluid about 85 percent ethylene glycol monoethyl ether by weight (Gosselin, 1976). The heaviest use of these products is in the original manufacture of the automobile and in replacing master cylinders. According to our discussions with automobile dealers, new automobiles and small trucks require about one quart of brake fluid, while medium and large trucks may require somewhat more. According to the U.S. Census Bureau's Industry Division (McGrath, 1982), 261,242 automobiles were built in California in 1980. Using production worker hour data (See Section 6.1), we estimate production of 130,750 trucks and buses in that year. Thus use of brake fluid in new vehicles would be 98,000 gallons. The solvent content of that volume would be 650,000 lb.

To estimate use of brake fluid in master cylinder replacement, we held discussions with automobile repair shops. Table 6.4-1 shows our estimate of the frequency of repair of vehicles of various ages. Total California vehicle registration and age distribution data were obtained from the State Department of Transportation (CDOT, 1981; Hoyt, 1982). The brake fluid was assumed to have the same density as the solvent. Master cylinder replacement results in the use of 1.7 million lb (850 tons) statewide. The total ethylene glycol monoethyl ether use in brake fluids in 1980 was 2.4 million lb (1,200 tons).

6.4.4   Other Automotive Products

Gasoline additives, carburetor cleaners, spray de-icers and engine cleaners contain solvents, including petroleum distillate, glycol ethers, ethylene glycol, methanol and xylene. Sales data for these products were unavailable. From very limited market data on two carburetor cleaners, we estimate use of 9,000 lb (4.5 tons) of xylene in this category.

6.5   INDUSTRIAL ADHESIVES AND SEALANTS

As noted above, information on a national survey of adhesives and sealants sales was provided by an industry source who wished to remain anony-

Table 6.4-1

ESTIMATION OF ETHYLENE GLYCOL MONOETHYL ETHER
USE IN MASTER CYLINDER REPLACEMENT

Age of Vehicle (years)	Pct. of Registered Vehicles[a]	Pct. Needing Master Cylinder Replacement	Brake Fluid (gal)	EGMEE Use (lb)
4 - 5	16.3	0	0	0
6 - 7	15.6	5	2.9×10^4	1.9×10^5
8 - 9	12.2	10	4.6×10^4	3.0×10^5
10 - 11	10.0	15	5.6×10^4	3.7×10^5
12 - 13	6.6	20	5.0×10^4	3.3×10^5
>13	10.4	20	7.8×10^4	5.2×10^5
Total			2.6×10^5	1.7×10^6

[a] Data supplied by California Department of Transportation (Hoyt, 1982).

mous. National use of solvent-based adhesives in 1981 was at least 135.2 million lb in 1981. To estimate California use, we multiplied the national use in four major industrial categories (construction, transportation, packaging and other) by the corresponding ratios between California employment and national employment in pertinent industries. In housing construction, for example, this ratio was 0.12. We estimate that a minimum of 16.6 million lb of industrial adhesives were used. The data on solvent content presented in Table 6.3-6 are probably not applicable to industrial adhesives. For lack of better information, we shall assume that the most common emission factor applied in the EDS for source classification code 4-02-007-01 (adhesives application), 1375 lb of organic gas emissions per 2000 lb of adhesives, is valid for the industry. The total solvent contained in the 16.5 million lb of industrial adhesives would therefore be 11.3 million lb (5,700 tons). To estimate how much of individual chemical species are present in industrial solvents, we assumed that the product mix would be in the same proportion as individual solvents are consumed by the adhesives and sealants industry, SIC 2891. Table 6.5-1 shows the proportion of each solvent, as determined by our direct solvent consumption survey. Each chemical's fraction was multiplied by the estimated total solvent use (11.3 million lb) to determine the amount of each chemical used as a solvent in adhesives. Results are also shown in Table 6.5-1.

It should be emphasized that use of solvents in adhesives in California is probably much higher. The U.S. market for adhesives has been estimated to be as high as 3.5 billion lb/year, of which about 2.8 billion lb/yr are solvent-borne (Layman, 1982). Our estimate may therefore be low by a factor of 20.

6.6   SUMMARY OF CALIFORNIA INDIRECT SOLVENT CONSUMPTION

Table 6.6-1 shows our estimates of the use of 22 individual solvents and two solvent classes (aliphatic and aromatic hydrocarbons not otherwise specified) in the formulations we investigated. Paints, coatings and associated thinners account for about two-thirds of the 593.9 million lbs (297,000 tons) of indirect solvent use. The next largest category is automotive products, chiefly because of the major use of ethylene glycol in radiator antifreeze.

Table 6.5-1

SOLVENTS INCORPORATED IN INDUSTRIAL ADHESIVES
IN CALIFORNIA

Chemical	Percent of SIC 2891	Use in Adhesives (1000 lb)
Acetone	2.14	241.5
Butyl acetate	0.30	33.8
Butyl alcohol	0.06	7.1
Cyclohexanone	1.44	162.7
Diethylene glycol mono-ethyl ether	0.02	2.0
Diethylene glycol mono-methyl ether	0.04	4.0
Dimethyl formamide	1.53	172.5
Ethylene glycol mono-butyl ether acetate	0.04	4.6
Ethanol	0.05	5.7
Ethyl acetate	0.21	23.9
Ethyl benzene	-0-	-0-
Ethylene glycol	0.18	20.1
Ethylene glycol mono-butyl ether acetate	0.04	4.6
EG monoethyl ether	0.01	1.5
EG monoethyl ether acetate	0.06	6.4
Furfuryl	0.01	1.5
Heptane	1.47	166.4
Hexane	6.52	736.2
Isopropyl alcohol	0.36	40.3
Kerosene	1.22	138.2
Lacquer thinner	0.15	17.2
Methanol	0.24	27.2
Methyl chloroform	9.27	1,047.1
Methyl ethyl ketone	12.23	1,382.4
Methylene chloride	1.66	187.1
Methyl isobutyl ketone	0.01	1.1
Mineral spirits	32.96	3,724.0
Pentoxone	0.01	1.5
Perchoroethylene	0.03	3.8
Propanol	0.01	1.3
Propylene glycol	0.05	5.1
Toluene	5.56	628.0
Trichloroethylene	0.58	65.9
VM & P naphtha	6.94	783.7
Xylene	0.11	12.8
Miscellaneous	14.5	1,643.4
Totals	100.0	11,304.6

Table 6.6-1

SUMMARY OF SAI ESTIMATES OF CALIFORNIA USE OF MAJOR
SOLVENTS IN FORMULATIONS IN 1980
(Use in 1000 lb)

Solvent	Paints and Coatings	Thinners	Personal Care	Household Products	Automotive Products	Industrial Adhesives	Total
Acetone	4,400	9,700	800	370	-	242	15,512
Butyl acetate	8,200	1,800	82	12	-	34	10,128
Butyl alcohol	9,200	400	-	-	-	7	9,607
Ethyl acetate	6,500	4,700	85	63	-	24	11,372
Ethyl alcohol	4,900	14,800	3,040	-	-	6	22,746
Ethylene glycol	6,300	-	-	37	165,000	20	171,357
EG monobutyl ether	7,200	2,600	-	700	-	-	10,500
EG monoethyl ether	7,200	2,600	-	1,200	2,400	2	13,402
Hexane	-	-	-	600	-	736	1,336
Isopropyl alcohol	6,300	6,300	2,300	420	-	40	15,360
Methyl alcohol	5,000	4,100	-	-	15,900	27	25,027
Methyl chloroform	-	-	-	160	-	1,047	1,207
Methylene chloride	600	200	-	93	-	187	1,080
Methyl ethyl ketone	16,600	20,400	-	-	-	1,382	38,382
Methyl isobutyl ketone	11,300	800	-	-	-	1	12,101
Perchloroethylene	-	-	-	98	-	4	102
Propyl acetate	4,400	1,200	-	-	-	-	5,600
Propyl alcohol	-	-	-	-	-	1	1
Propylene glycol	4,000	-	312	-	-	5	4,317
Toluene	26,900	22,600	104	381	-	628	50,613
Trichloroethylene	-	-	-	30	-	66	96
Xylene	32,900	13,900	1	1	9	13	46,824
Aliphatic HC	83,400	13,300	-	39	-	4,812	101,551
Other aromatic HC	9,100	5,900	-	-	-	-	15,000
Other	4,800	3,900	-	-	-	2,016	10,716
Totals	259,200	129,200	6,724	4,204	183,309	11,300	593,937

As noted previously, the estimate for use of solvents in industrial adhesives may be an order of magnitude too low.

Apart from ethylene glycol, the most heavily-used solvents in formulations are the unspecificed aliphatic hydrocarbons, including mineral spirits, VM & P naphtha, and kerosene. These account for almost 51,000 tons.

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